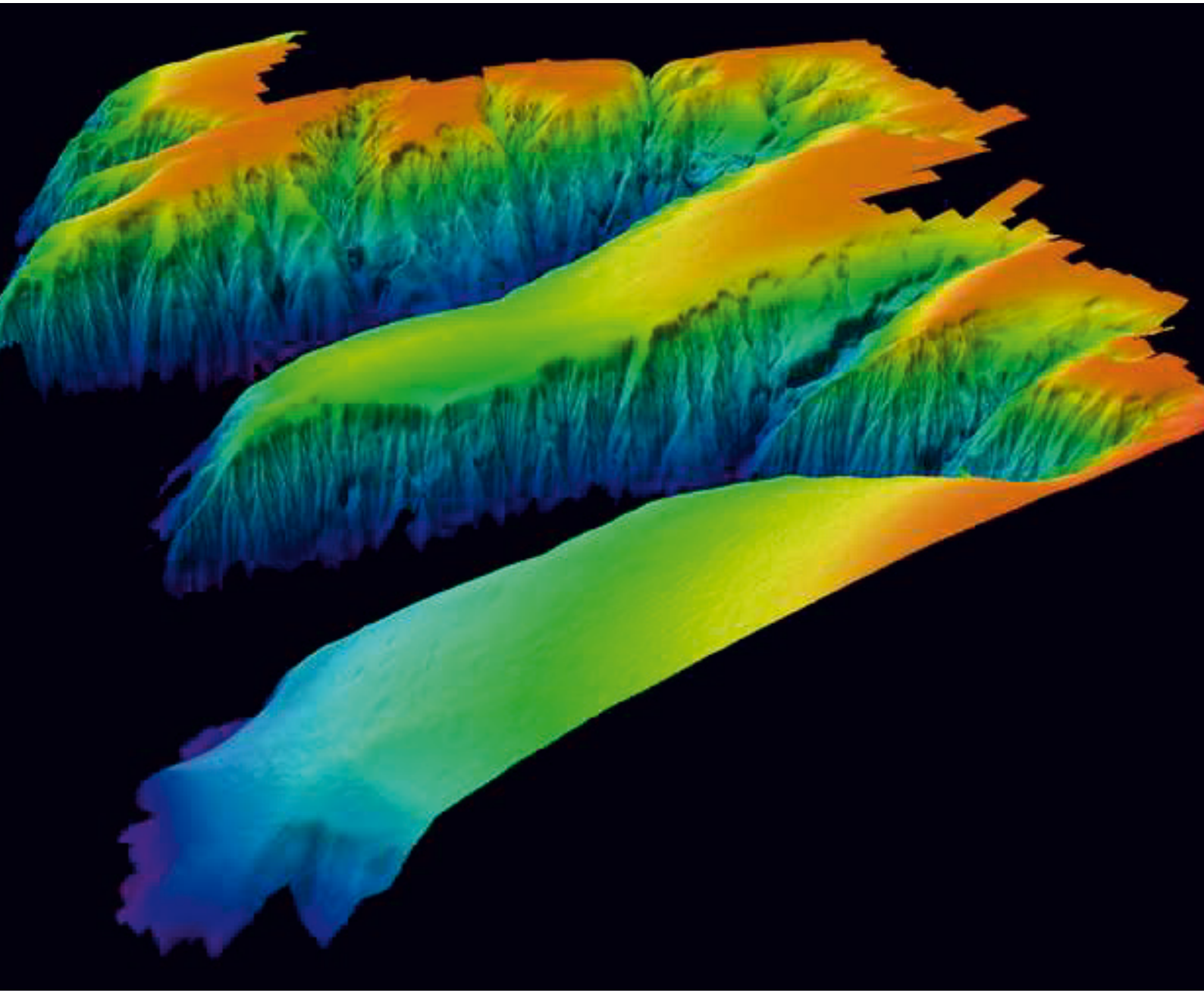
2nd International Symposium on Submarine Canyons, Edinburgh 2014

Abstracts



British Geological Survey

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Front Cover: Shaded relief image of multibeam bathymetry data acquired over the Dangeard and Explorer Canyons, South Western Approaches UK. Water depths displayed are between 138 and 1165 m. The area comprises a dendritic network of gullies feeding into the canyon thalwegs, cold-water mini-mounds occur on the canyon interfluves.

International Network for submarine Canyon Investigation and Scientific Exchange

Interest in submarine canyons is growing due to their complexity, the variety of processes taking place and the resulting diversity of their habitats. The aim of the INCISE network, and specifically this 2nd International Symposium on Submarine Canyon (INCISE2014 for short) is to bring together the community of submarine canyon scientists to stimulate cross-discipline discussions, leading to integrated research tackling the essential questions that will increase our understanding of these systems.

INCISE, the International Network for submarine Canyon Investigation and Scientific Exchange, was established in 2012, when the first meeting was held at Ifremer in Brest (France). Submarine canyons are complex and important bathymetric features that can be found around the world. Despite their widespread occurrence, little is known about their formation, sedimentary processes, oceanography and faunal communities, leaving important questions about their sustainable management and the potential use/protection of the resources they host. INCISE was formed to address these questions and aid scientific exchange between submarine canyon researchers. In addition to organising symposia, INCISE contributes to science through various outputs. For example, the first meeting resulted in a special issue of Deep-Sea Research II published in June 2014 (http://www.sciencedirect.com/science/journal/09670645). For this second symposium, we aim to set up a number of active working groups, covering a range of current submarine canyon topics and driving forward the international submarine canyon research.

So, how better to start such an initiative by meeting with the top researchers in the field, presenting our latest research and discussing the newest findings? We hope you will enjoy the 2nd International Symposium on Submarine Canyons, and very much look forward to all the contributions and discussions!

Welcome to Edinburgh,

Welcome to INCISE2014!

Jaime Davies
Veerle Huvenne
Heather Stewart
Sophie Green
Lenaick Menot
Rob Hall
Peter Harris
Aaron Micallef
Joshu Mountjoy
Steve Ross
Nathalie Valette-Silver

SESSION 1: CANYON PROCESSES IN THE SPACE-TIME CONTINUUM (FORMATION, EVOLUTION, CIRCULATION)

A MODEL FOR CANYON GEOMORPHIC EVOLUTION IN TECTONICALLY-ACTIVE CONTINENTAL MARGINS

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Active tectonic margins comprise a significant proportion of global continental margins and host more than half of submarine canyons worldwide. Understanding the coupling between tectonic forcing and canyon processes is important to improve modelling of canyon evolution and derive tectonic information from canyon morphology. In this study we use high resolution geophysical data and imagery from the Cook Strait submarine canyon system, which incises the Hikurangi Margin off New Zealand's North Island, to propose a generalised model of canyon development in response to tectonic forcing (Figure 1).

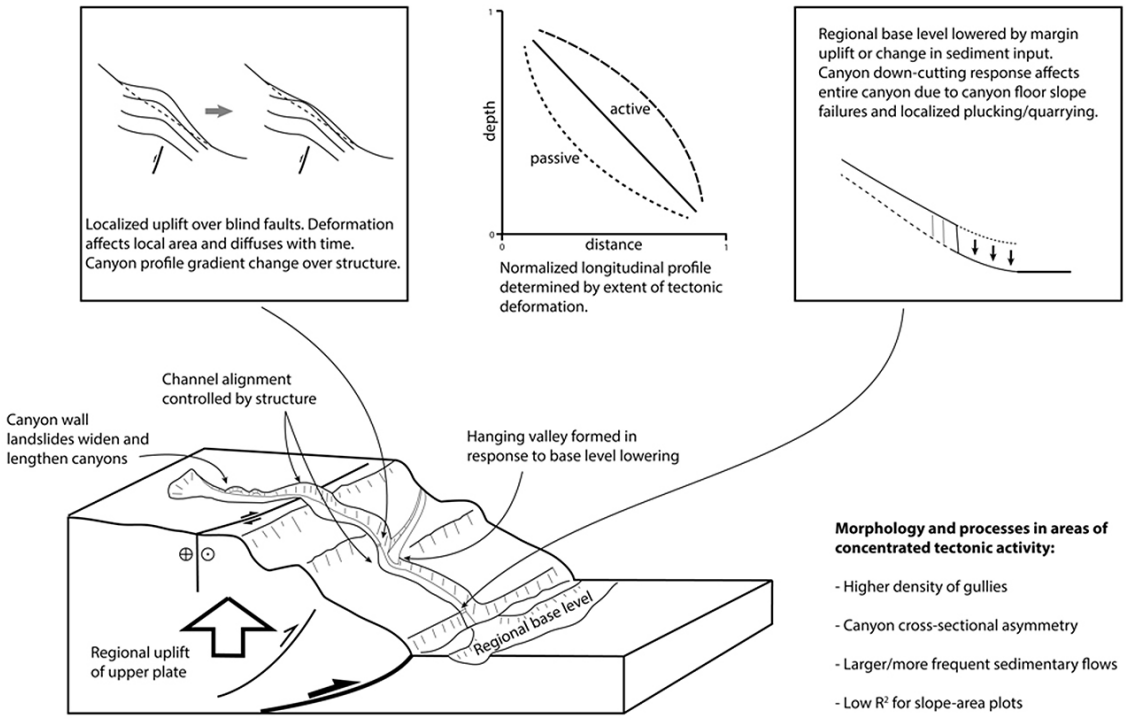

Figure 1 Summary model illustrating modes of canyon response to active tectonic processes.

SOURCES AND SINKS OF BAROCLINIC ENERGY ALONG THE CELTIC SEA SHELF SLOPE: THE EFFECT OF CANYONS AND CORRUGATIONS

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Internal tides are a ubiquitous feature of the hydrodynamics within and around submarine canyons along continental shelf slopes. Canyons can be both a source and a sink of baroclinic (internal) energy: a source due to internal tide generation by barotropic (surface) tidal flow across the steep canyon walls/floor; a sink due to topographic focusing of baroclinic energy towards the canyon floor/head and eventual dissipation by nonlinear processes upon critical reflection. Tidal currents are typically orientated along shelf slopes so any incisions into the slope (i.e., canyons) will tend to increase the across slope flow that, along with a stratified watercolumn, is required for internal tide generation. As well as dissipating baroclinic energy, canyons may also enhance negative barotropic-to-baroclinic energy conversion (i.e., transfer of baroclinic energy back to the barotropic tide) by the superposition of locally and remotely generated internal tides. Here we use a regional tide model to assess the effect of canyons and other corrugations along the Celtic Sea shelf slope on the local and remote internal tide fields. A series of model simulations are compared, with progressively smoothed bathymetry to remove the canyons and corrugations. Most of the bathymetric features along the slope are sources of baroclinic energy, affecting the internal tide field several 100s km offshore in the North Atlantic. By contrast Whittard Canyon is a sink of baroclinic energy, both through dissipative processes and negative barotropic-to-baroclinic energy conversion.

INTERNAL WAVES IN WHITTARD CANYON

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Whittard Canyon is one of the major submarine canyons that incise the Celtic Sea shelf edge. The Celtic Sea, located off the south coast of Ireland, is a 100–200 m deep shelf sea that is notable for the presence of large tidal currents and strong seasonal fluctuations in surface heating and cooling. The shelf edge is a region of rough topography and barotropic tidal flows generate internal waves and associated baroclinic energy fluxes. These internal tides are reflected if they encounter topographic features such as submarine canyons, however, the reflection is dependent on the relative topographic slope and can be subcritical (waves continue to shoal if approaching from offshore), supercritical (waves are reflected back into deep water) or critical (nonlinear effects, potential wave breaking and turbulent mixing).

Submarine canyons are known to trap and focus internal waves towards the head of the canyon, leading to high levels of turbulent mixing. This mixing may drive vertical nutrient fluxes and enhance primary productivity at the shelf edge. Whittard Canyon is dendritic and has a variably u- and v-shaped cross-sectional profile, providing many different topographic slope values and hence many different reflection scenarios. Using a numerical model, I investigate the propagation of internal waves through Whittard Canyon using realistic and idealised bathymetry and also attempt to identify local and remote internal wave generation sites within the region. Preliminary model runs indicate that the energy flux in Whittard Canyon is up-canyon (on-shelf), which differs to the surrounding shelf region where the energy flux is off-shelf. This indicates that Whittard Canyon significantly modifies the internal wave field in the region, with potential implications for primary productivity and benthic faunal communities within the canyon.

ROLE OF HUDSON CANYON AS THE SOURCE OF THE US EAST COAST NON-SEISMIC TSUNAMIS

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This study investigates the role of Hudson Canyon in generation of several non-seismically generated tsunamis offshore the East Coast of the U.S. On April 11, and June 13, 2013 two long-period water level anomalies were recorded at different locations along the northeastern seaboard of the United States. Wave amplitudes reached almost a half meter in deep water, as recorded at DART buoy 4402 and close to 1 meter at coastal tide gauges in Rhode Island, Massachusetts, New York and New Jersey. Smaller signatures were seen in tide gauges as far away as Bermuda and Puerto Rico. There seems to be circumstantial evidence indicating a meteorological origin for the June 13 event, however, that explanation is less compelling for the event of April 11. Tsunami wave travel time contours trace the origin of both perturbations back to an area located in the vicinity of Hudson Canyon. A model using a source just shoreward of the canyon shows arrival times that agree well with data at both the DART buoy and the tide gauges, but fails to reproduce some large amplitude waves within Delaware Bay that may, indeed, be atmospherically forced.

The present study is an attempt to identify possible sources of this non-seismic tsunami, primarily located along the continental break outside of the Hudson Canyon. While the source of the waves for at least two tsunamis appear to be associated with the Hudson Canyon, the definitive evidences for either the landslide or the meteorological origins for those waves are still uncertain. Preliminary bathymetric survey of the walls of Hudson Canyon by the NOAA Ship *Okeanos Explorer's* did not find any recent landslide evidence. Failure to identify any such sources strengthen the hypothesis of a meteo-tsunami, but the exact mechanism linking the gravity wave generation with the Hudson Canyon is not yet clear. Positive identification of potential landslide sources may open up additional lines of investigation as to the real source of the event.

TEMPORAL EVOLUTION OF CURVATURE-INDUCED SECONDARY FLOWS DURING PASSAGE OF A TURBIDITY CURRENT IN A SUBMARINE CANYON BEND

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Turbidity currents are remarkable processes capable of transporting sediment from shallow continental shelves, through submarine canyons and channels, to deep ocean basins over distances as large as 1,500 km. During transport, morphodynamic interactions between the flow and the seafloor ultimately control the architecture and distribution of the deposited sediment. The resulting bathymetry has an important influence on the distribution of marine benthos, while understanding the depositional architecture of such deposits is necessary to efficiently produce hydrocarbons from submarine reservoirs. Turbidity currents are also potential geohazards which are capable of damaging strategically important subsea cable networks and expensive oil and gas infrastructure. Hence, characterising such flows is important. The detailed flow fields within submarine channel bends has recently been shown to be sensitive to the character of the velocity and density profiles: secondary flow orientations at bend apexes become reversed relative to those found in sub-aerial river bends as the velocity maximum and density maximum move closer to the bed. However, despite its importance in governing sedimentation patterns and system evolution, the difficulties in acquiring direct measurements of submarine turbidity-driven flow means that the detailed flow structure in such settings remain poorly constrained. Indeed, a number of studies based primarily on physical and numerical models have yielded contradictory results on the controls on secondary flow orientation.

Here we present the first successful and direct measurements of secondary flows of large-scale turbidity currents in a bend within the Congo Canyon. We show and detail how the secondary flow patterns evolve during the passage of the current and we link this behaviour to key features of the turbidity current and its evolution. The paper will highlight and discuss the implications of the results for the dynamics and deposits of submarine channel settings.

SUBMARINE CANYON SYSTEMS OF THE CALABRIAN MARGIN: CENTRAL MEDITERRANEAN SEA

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Submarine canyons occur on both passive and active continental margins worldwide, as single features or arranged in hierarchic systems that may or may not be a) river-associated, b) shelf- or slope incising and c) headed or blind. They operate over geological timescales and thus provide important connections from coastal areas to deep basins. Canyon systems on active margins may generate geohazards both for coastal infrastructures (harbors, railways…), due to the retrogressive activity of their heads, and to seafloor-anchored infrastructures, as they are able to transfer energetic turbidity flows to the deep basin and to generate mass wastings of various sizes and volumes. Finally they are important for benthic ecosystems and they contain the highest litter density in the oceans. Thus a correct understanding of their dynamics and potentials is important to identify and protect vulnerable marine settings.

The Mediterranean Sea is characterized by remarkably young canyons, many strongly conditioned by the km-scale lowering of sea levels during the Messinian salinity crisis ca. 5.5 Ma, and others on active margins formed after the Messinian. Here we present new information from the active continental margin of Calabria, which is densely incised by submarine canyons that have formed in response to ongoing km-scale uplift of Calabria over the last ca. 1 Ma. Despite their young age, they incise the slopes and (narrow) shelves of Calabria over lengths of hundreds of kilometers, with thalwegs 2 km wide, walls higher than 200 m and headwalls, when characterized by dendritic morphology, that can extend over 100 km. Most of these Pleistocene canyons are not isolated, but form hierarchic systems with five or more canyons merging to build dendritic systems that may or may not be connected to onshore drainage networks. We present information on their geomorphic attributes and examine their origin and evolution in relation to tectonic and sea level changes during the Pleistocene, and consider, their potential as marine geohazards.

POLAR SUBMARINE CANYONS ARE TWICE THE AVERAGE SIZE OF NON-POLAR CANYONS – WHY?

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A new global database of submarine canyon geomorphic metrics has been produced based on the analysis of the SRTM30_PLUS bathymetric grid. "Large" canyons were mapped, including 2,076 shelf-incising and 7,401 blind canyons. Measurements were taken of canyon area, length, depth of incision and percentage area of steep-slope (escarpments), exceeding 15° (methods described in Harris et al., 2014).

Polar submarine canyons are twice the size of those in non-polar regions. Canyons in the Arctic have an average size of 890 km^2 and in the Antarctic the average canyon size is 997 km2, compared to the overall (global) average size of 463 km^2. Earth's largest four canyons are all located on polar slopes. Canyons comprise an average of 11.2% of the continental slope area, attaining maxima of 16.1% of the continental slope of the Arctic Ocean and 15.1% of the Antarctic continental slope. Polar, shelf-incising canyons are more deeply incised into the slope, to mean depths of around 1,600 m and are greater in average length than non-polar canyons. The question arises: why are polar canyons larger than non-polar canyons? The following points are relevant:

- Shelf incising canyons are over twice the mean size of blind canyons on average (780 km^2 and 380 km^2, respectively) and greater in mean length (54.8 and 37.3 km, respectively)
- Shelf incising canyon formation is thought to be controlled by the rate of terrigenous sediment discharge to the slope1
- Over geologic timescales, sediment export from glaciated continents greatly exceeds export from non-glaciated continents
- Therefore, slopes adjacent to glaciated continents have more shelf-incising canyons and thus a greater number of large-sized canyons than slopes adjacent to non-glaciated continents

Although polar submarine canyons are the largest on Earth, the pattern for shelf incising and blind canyons is reversed between the Arctic and Antarctic: whereas shelf incising canyons in the Arctic Ocean have the greatest mean length, greatest depth of incision and greatest average area, for blind canyons it is the Antarctic that has the greatest mean length, greatest depth of incision and greatest average area. We suggest it is the difference in timing of sediment input between the Arctic and Antarctic that explains the observed geomorphic difference. Whereas continental glaciation and consequent sediment input to the Arctic margin has occurred mainly during the Pleistocene, the Antarctic glaciation has been ongoing shelf incising canyons that have been disconnected from terrigenous (glacial) sediment input over geologic timescales.

[1] Harris, P.T., MacMillan-Lawler, M., Rupp, J., Baker, E.K., 2014. Geomorphology of the oceans. Marine Geology 352, 4–24.

[2] Harris, P.T., Whiteway, T., 2011. Global distribution of large submarine canyons: geomorphic differences between active and passive continental margins. Marine Geology 285, 69–86.

PROCESSES INFLUENCING GULLY FORMATION ON HIGH-LATITUDE CONTINENTAL MARGINS

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Submarine gullies are common features of high-latitude continental slopes. Analyses of gully parameters and spatial distributions provide a step forward in constraining processes operating on continental margins and environmental controls influencing gully morphology. Here we identify six distinct gully types from quantitative analysis of multibeam bathymetric data along >3000 km of high-latitude outer shelf and upper slope. Gully morphology was found to vary with local slope character (slope geometry, gradient), regional factors (location of cross-shelf troughs, trough mouth fans and drainage basin size), sediment yield and ice-sheet history. Cascading flows of cold, dense water, previously thought to have caused widespread gully erosion, is not likely to have formed deeply eroded and V-shaped gullies observed over much of the Antarctic margin. Instead, V-shaped and deeply eroded gullies were likely formed by turbidity currents initiated by processes such as sediment-laden subglacial meltwater released from beneath an ice sheet and resuspension of sediment by intense iceberg scouring. Gullies were also found to be influenced by small-scale mass wasting. Submarine gullies also occur on the flanks of high-latitude deep-sea sediment drifts, ocean ridges and volcanic flanks. The morphology and formation mechanisms of these gullies are, however, unknown. It is clear that the gullies could not have formed by sediment-laden subglacial meltwater release, one of the main processes influencing gully formation on both Arctic and Antarctic continental margins. This is because the depths at which the deep-sea sediment drifts or ocean ridges occur prevent ice-sheet grounding, thus prohibiting subglacial meltwater release. As yet, it is unclear what processes are influencing gully formation in these areas and whether similar processes are acting on the continental margins. Understanding how these mechanisms differ is fundamental in understanding seafloor erosion patterns, ice-dynamic histories, continental margin and canyon evolution and factors influencing slope instability.

CONTOURITE CHANNELS IN THE MID-SLOPE GULF OF CADIZ, NORTH ATLANTIC

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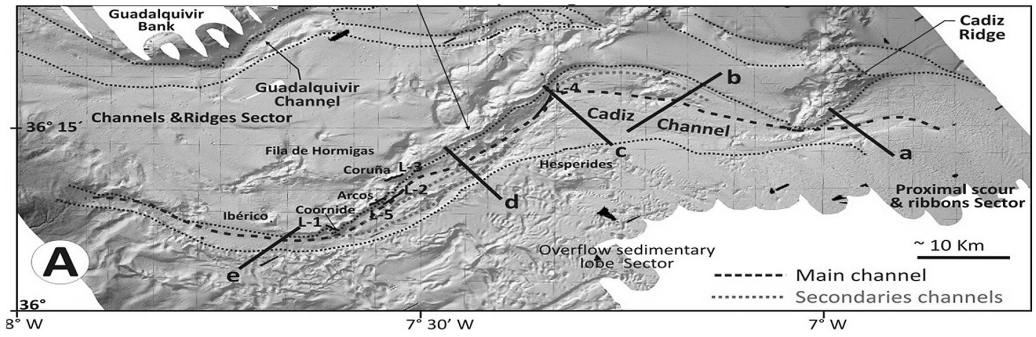
In the middle slope of the northern Gulf of Cadiz there are up to nine separate contourite channels. These are due to a combination of the strongly erosive action of bottom currents, as they descend the continental slope, and neotectonic activity that creates diapirism and morphological barriers to flow. The five larger channels are known as the Cadiz, Guadalquivir, Huelva, Diego Cao and Gusano channels. Of these, the Cadiz Contourite Channel is one of the largest and most prominent of its type in the world. It shows some similarities with other deepwater channels and canyons, such as those formed by downslope turbidity current processes, but has a different origin and is floored by contourite sands rather than turbidites. It is therefore very significant for our scientific understanding of different channels types in deepwater – their processes, sediments and environmental habitats.

The Cadiz Contourite Channel is known to siphon off the southern branch of the Lower Core of Mediterranean Outflow Water (MOW) as it flows westwards from the Gibraltar Gateway. It is 150 km long, 2–12 km wide, up to 120 m deep, and broadly s-shaped in plan view. It has several associated subparallel marginal channels and shorter spillover channel segments. Bottom photographs and dredge hauls reveal a high-energy channel floor, in places with bare rock, boulders and gravel, and elsewhere covered with sandy contourites. There is a range of benthic organisms that appear to flourish in this environment. The rocky substrate and derived clasts are formed of authigenic iron-rich carbonates. The sandy substrate shows a wide range of current-induced bedforms from small, straight-crested ripples to large sinuous sand waves and dunes, from weak surface lineation on sands to aligned gravel stringers and deep erosive scours around large boulders. Bedform orientation indicates flows directed to the south/south-west (main channel) and west (spillover channel), which can be related to MOW bottom currents, and current velocities that vary between about 0.2 and 0.8 ms^{-1}, even in the same channel location. Maximum current velocities are achieved by a combination of barotropic tides and internal tides (and their generation of internal waves) that reinforce the normal MOW flow. Shelf-generated internal waves of shorter period may exert an even greater influence on current intensity, when they occur at times of storm forcing. In all cases the canalising effect of the Cadiz Channel will amplify tidal influence.



SESSION 2: NEW WAYS TO STUDY SUBMARINE CANYONS: INTEGRATED PROGRAMMES, NEW TECHNOLOGY AND COORDINATED MONITORING EFFORTS

PROPOSAL FOR CO-ORDINATED INTERNATIONAL EFFORTS TO STUDY ACTIVE TURBIDITY CURRENT SYSTEMS AND THEIR DEPOSITS AT KEY TEST SITES

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Turbidity currents, and other types of submarine sediment density flow, arguably redistribute more sediment across the surface of the Earth than any other flow process. It is now over 60 years since the seminal publication of Kuenen and Migliorini (1950) in which they made the link between sequences of graded bedding and turbidity currents. The deposits of submarine sediment density flows have been described in numerous locations worldwide, and this might lead to the view that these flows are well understood. However, it is sobering to note quite how few direct measurements we have from these submarine flows in action. Sediment concentration is the critical parameter controlling such flows, yet it has never been measured directly for flows that reach and build submarine fans. How then do we know what type of flow to model in flume tanks, or which assumptions to use to formulate numerical simulations or analytical models?

It is proposed here that international efforts are needed for an initiative to monitor active turbidity currents at a series of 'test sites' where flows occur frequently. The flows evolve significantly, such that source to sink data are needed. We also need to directly monitor flows in different settings with variable triggering factors and flow path morphologies because their character can vary significantly. Such work should integrate numerical and physical modelling with the collection of field observations in order to understand the significance of field observations. Such an international initiative also needs to include coring of deposits to link flow processes to deposit character, because in most global locations flow behaviour must be inferred from deposits alone. Collection of seismic datasets is also crucial for understanding the larger-scale evolution and resulting architecture of these systems, and to link with studies of subsurface reservoirs. Test site datasets should thus include a wide range of data types, not just from direct flow monitoring.

This 'test site' initiative may be timely and feasible, due to recent technological advances in monitoring sensors, moorings and autonomous data recovery. This will be illustrated here by seminal field datasets recent collected by colleagues from the Squamish River Delta, Monterey Canyon, Congo Canyon and offshore SE Taiwan. This talk will conclude with some suggestions for appropriate test sites and collaborative approaches to future data collection.

Acknowledgements: This overview is based on a seminal body of recent flow monitoring work by international colleagues including John Hughes Clarke, Maria Azpiroz, Matthieu Cartigny, Michael Clare, Cortis Cooper, Stephanie Girardclos, Philip Hill, Gwynn Lintern, James Liu, Andrew Lin, Dan Parsons, Charlie Paull, Cooper Stacey, Esther Sumner, and Jingping Xu, amongst others.

BARKLEY CANYON AS A MODEL FOR LONG-TERM OCEANOGRAPHIC OBSERVATIONS AND DEEP-SEA MANIPULATIVE EXPERIMENTS

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Barkley Canyon (BC) located in the NE Pacific offshore Vancouver Island is influenced by a myriad of physical and geological processes that play an important role in the distribution of benthic and pelagic communities. BC incises the continental shelf, extending from around 200 m depth at its head, down to greater than 2000 m depth where it opens into the abyss on the lower continental slope. The canyon also cuts across the active Cascadia Subduction zone. In the middle section of the canyon, pressure, temperature, gas saturation, and local biological and chemical conditions are just right for exposed gas hydrates to be stable on the seafloor. BC has being one of the few canyons in the world where detailed observational and modeling studies have aided the characterization of the role of canyons in the onset of upwelling events and the subsequent enrichment by phyto-and zooplankton communities. BC is also unique in the sense that it is likely the most heavily instrumented submarine canyon worldwide, benefiting from the presence of the NEPTUNE cabled observatory, operated by Ocean Networks Canada (ONC). The cable array has 4 main instrument platforms inside the canyon (depths ranging from 890 to 1000 m) plus an instrument platform on the upper slope outside of the canyon topography (396 m). Instruments include ADCPs (9), CTDs (5), rotary imaging sonars (3), fixed seafloor video cameras mounted on pan/tilt systems (3), sediment traps (2) bottom pressure recorder (1), broadband seismometer (1), hydrophone (1), vertical profiling system (1), and a benthic crawler vehicle outfitted with multiple environmental sensors and two video cameras. All data collected by these instruments are available online through ONC's data portal *(Oceans 2.0* – Ex: Figure 1), and scientists all over the world have free access for the purpose of conducting scientific research. Currently, BC also serves as a site for long-term, deep-sea manipulative experiments, including sediment enrichment experiments (with ^{13}C-labeled microalgae), disturbance experiments by placement of organic and inorganic substrates (wood parcels, whalebones and authigenic carbonates), and population/genetic connectivity experiments (larval colonization frames).This paper aims to inform the international submarine canyons research community of possible work that could be undertaken in BC utilizing data from the NEPTUNE cable array. Current research themes include from ocean circulation, climate change and carbon flux, deep-sea biodiversity and function, gas-hydrate dynamics, etc. These research themes align with the 5 core INCISE objectives, and therefore we foresee many collaborative projects between ONC (Neptune) and the INCISE network potentially emerging after this symposium in Scotland.

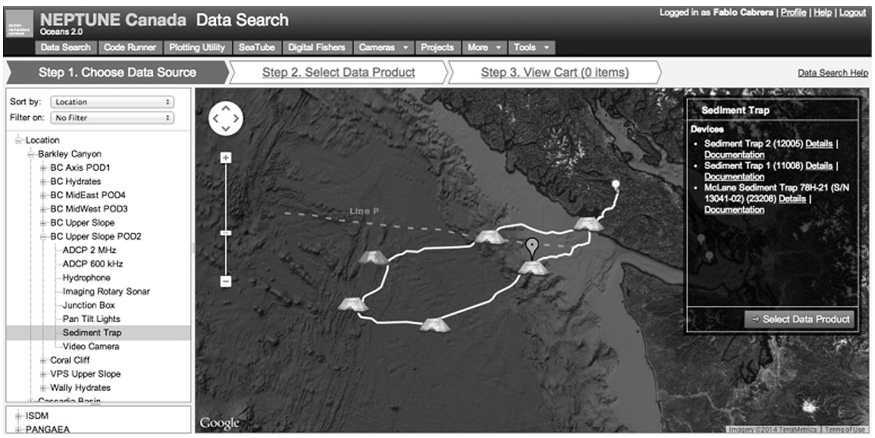

Figure 1 Ocean Networks Canada Oceans 2.0 Data portal. The tool 'Data Search' allow scientists to browse and download available data, sorting by location or instruments.

THE DEVELOPMENT OF AN INNOVATIVE UNDERWATER VEHICLE AT IFREMER TO MEET NEW SCIENTIFIC EXPLORATION CHALLENGES

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The ever increasing demand for biological and acoustic data of the underwater environment has prompted the French oceanographic institute IFREMER to design a new vehicle to meet novel scientific exploration challenges. The main objective of this new hybrid underwater robotic system (HROV) is to combine the ability to gather high resolution data and perform inspection and intervention tasks while maintaining operational costs to a minimum. This will enable wider access by the scientific community to highly specialized vehicles designed to meet their goals. The talk will report on the overall vehicle design and its several innovative aspects such as the global architecture and the deployment method. The new vehicle that will join the Institute's operational fleet in 2015 targets precisely mapping, sampling and monitoring tasks through the implementation of a hybrid architecture to bridge between canonical ROV and AUV systems.

The implementation of this new underwater vehicle responds to novel challenges in oceanographic science. The requirements of the scientific community was to explore and perform intervention tasks in natural environments whose morphology represents an impediment to existing underwater vehicles. Such environments include underwater canyons, seamounts, ridges rift valley walls and continental margins, where the predominantly rocky or hard substrate favors the development of rich faunal settlements. These rich yet extremely vulnerable marine ecosystems (VME) are exposed to ever growing threats represented by human activity; the European Marine Strategy Framework Directive issued in 2008 requires the mapping and the monitoring of these VME in order to assess their overall conditions by 2020. Sea trials are planned for 2015. These cruises will allow scientists familiar or not with deep-sea under-water vehicles to validate the new functionalities in the framework of the European Marine Strategy Directive: assessing ecological status of benthic marine ecosystems, from 50 to 2500 meters deep.

CAN WE USE HISTORICAL OBSERVATION DATA FOR HABITAT SUITABILITY MODELLING? A CASE STUDY FROM BALTIMORE CANYON, NW ATLANTIC

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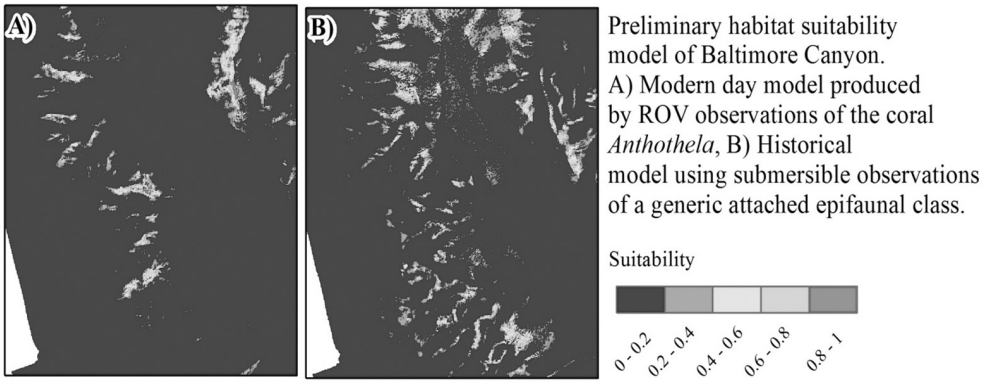
Habitat suitability modelling has emerged as a useful tool to guide surveys and conservation in hard to study regions such as the deep ocean. In this study, we utilised historical observation data from the 1980's as a precursor to sampling Baltimore Canyon in the North West Atlantic Ocean as part of a multidisciplinary project. We attempt to assess whether historical observations can be used to guide modern-day surveys in order to focus research efforts into areas that contain potentially suitable habitat for target species. Historical observations were collected from five Johnson-Sea-Link (JSL) submersible research dives in the 1980s to assess the functioning of several canyons on the NW US shelf (cruises collated by Hecker et al. 1983). In total, 58 positive position fixes of the JSL were acquired, from these we generalised the observations at these sites into the generic classes of 'attached epifauna' and 'hard grounds' for comparison with modern day observations. The JSL videos revealed that Baltimore Canyon contained hard and soft corals. During BOEM cruises in 2012 and 2013, we undertook sixteen ROV dives using both the *Kraken II* and *Jason II* ROVs in various areas of Baltimore Canyon. Using both sets of observation (modern and historical), we utilised the Maxent modelling approach in association with several multibeam sonar-derived terrain variables to identify areas of suitable habitat for attached 'fauna' and also for 'hardgrounds'. Preliminary models show that the historical data offer some potential for guiding sampling, but modern observations are more accurate, have greater taxonomic distinction and ultimately produce more useful models.



Preliminary habitat suitability model of Baltimore Canyon. A) Modern day model produced by ROV observations of the coral *Anthothela*, B) Historical model using submersible observations of a generic attached epifaunal class.

PREDICTIVE ENSEMBLE MAPS FOR COLD-WATER CORAL DISTRIBUTIONS IN THE CAP DE CREUS CANYON (NW MEDITERRANEAN)

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Predictive habitat mapping has shown great promise to improve the understanding of the spatial distribution of benthic habitats. However, although they surely represent an important step forward in process-based ecosystem management, their predictive efficiency is not always tested by independent groundtruthing data. This is particularly true for the deep-sea environment, where sample data are always limited compared to the large extent of the areas to be mapped. The aim of this study is to apply and test different spatial models to statistically predict the distribution of three Cold-Water Coral (CWC) species (*Madrepora oculata, Lophelia pertusa* and *Dendrophyllia cornigera*) in the Cap de Creus Canyon (NW Mediterranean), based on high-resolution swath-bathymetry data and video observations from the submersible JAGO (IFM-GEOMAR). Submarine canyons act as specific hosting areas for CWCs, owing to their favourable environmental conditions, which provide habitat and shelter for a wide range of species, including commercially viable fish. Maximum Entropy (MaxEnt), General Additive Model (GAM) and decision tree model (Random Forest) were independently applied to represent non-linear species-environment relationships using terrain variables derived from multibeam bathymetry (slope, geomorphologic category, rugosity, aspect, backscatter). Relevant differences between the three models were observed. Nonetheless, the predicted areas where CWCs should be found with higher probabilities coincided for the three methods when a lower spatial scale was considered. According to the models, CWCs are most likely to be found on the medium to steeply sloping, rough walls of the southern flank of the canyon, aligning with the known CWC ecology acquired from previous studies in the area. As a final step, a probabilistic predictive ensemble has been produced merging the outcomes of the three models considered, providing a more robust prediction for the three species. The main insight is that important discrepancies can arise in using different species distribution models, especially when high spatial resolutions are considered. This could in part be the result of the different statistical assumptions behind each of the models. We suggest that a more reliable prediction could be obtained by merging models into spatial ensembles, able to reduce differences and associated uncertainties, showing hence a strong potential as an objective approach in the planning and management of natural resources.

NOAA SHIP OKEANOS EXPLORER SUBMARINE CANYON MAPPING EXPLORATIONS

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Between 2011 and 2014, the NOAA Ship *Okeanos Explorer*, operated by the NOAA Office of Ocean Exploration and Research and the NOAA Office of Marine and Aviation Operations, conducted 23 exploration cruises over submarine canyons along the U.S. Atlantic continental shelf break and within the Gulf of Mexico. Along the U.S. Atlantic shelf, sonar mapping efforts focused on the continental slope from North Carolina to the U.S.-Canada maritime border, including every major shelf-breaching canyon, minor slope-confined canyon, and 'canyonized' area in between. In the Gulf of Mexico, efforts focused on Keathley, Bryant, Mississippi, and Green Canyons, and the 'canyonized' areas of the West Florida Escarpment. Ultimately, over 125,000 square kilometers of canyon areas were mapped using the ship's multibeam, splitbeam, and subbottom sonars, and 48 ROV dives collected hundreds of hours of high-definition imagery of previously unexplored areas. Collectively, the 23 cruises produced numerous discoveries, including previously unknown cold water seeps, chemosynthetic communities, and methane hydrate deposits, a surprising diversity and distribution of deepwater corals and sponges, and new evaluations of canyon wall breaches and failures. The rapid data sharing policy of the *Okeanos Explorer* program has led to follow-on investigations by NOAA and its partners, and the unique telepresence capabilities of the ship allowed for increased public participation in canyons exploration. Well over a hundred scientists on shore provided scientific insight into the Atlantic Canyons and Gulf of Mexico ROV cruises, creating cross-discipline collaboration and enriched narration for the hundreds of thousands of members of the public who tuned in via live internet feeds.

SESSION 3: PATTERNS IN SUBMARINE CANYONS: ROLE OF SCALE AND HETEROGENEITY

AN INTEGRATED APPROACH TO PREDICTIVE HABITAT SUITABILITY MODELING AND FIELD SURVEYS IN NORTHWEST ATLANTIC SUBMARINE CANYONS: MODEL VALIDATION AND HABITAT/FAUNAL CHARACTERIZATION

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Seafloor surveys using the towed camera system *TowCam* were used to document deep-sea coral locations in submarine canyons off the northeastern United States and to characterize benthic ecosystems and habitats. Based on results of a habitat suitability model, *TowCam* was deployed in areas with different levels of predicted habitat suitability. A total of 35 digital image *TowCam* surveys were completed and more than 91,741 images taken of these canyon systems including Tom's, Hendrickson, Veatch, Gilbert, Ryan, Powell, and Munson Canyons, one minor and two intercanyon areas, in order to collect contemporary deep-sea coral and sponge distribution, abundance, and habitat data. The model successfully predicted most of the 'hotspots' of high coral abundance and/or diversity surveyed, including previously unsampled areas. Coral presence/absence information was collected and habitats characterized. Significant differences in species composition and distribution were observed and appear to be driven by habitat and depth. High abundances and diversity of scleractinians, antipatharians, octocorals and sponges were correlated with vertical canyon walls, margins, sediment, cobble, boulders, and coral rubble habitat. The ability to locate and define the composition and distribution of vulnerable marine ecosystems, as well as to validate predictive species distribution modelling is critical for management and conservation of living resources. Integrated field/modelling efforts support development of accurate maps and fine-scale models needed for planning processes.

PARTICLE TRANSPORT AND DEPOSITION IN NORFOLK AND BALTIMORE CANYONS, NW ATLANTIC

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The Mid-Atlantic Bight is incised by several large canyons, two of which (Baltimore and Norfolk canyons) were studied as part of a multidisciplinary project initiated by the Bureau of Ocean Energy Management (BOEM, USA) and jointly funded by BOEM, NOAA and USGS. The heads of the canyons, which are 140 km apart, both lie at a distance of 90 km offshore on the same shelf margin and lack direct input from rivers. Because of their proximity to each other and the similar large-scale setting we hypothesized that the two canyons would have comparable distributions of sediment and organic matter, and consequently also have comparable benthic faunal communities. Core-samples were collected along the canyon axes and on the adjacent slope and analyzed for sediment composition (grain size, XRF), sedimentation rate (^{210}Pb) and organic matter (C, N, pigments). Additionally, water column properties, including turbidity, were measured with a CTD on transects along and across the axes and at selected yoyo stations. A distinct turbidity plume was observed between the 350–1000 m contour within Baltimore canyon, and this plume pattern may be related to the presence of an internal tidal bore. In contrast, turbidity in Norfolk canyon was more evenly distributed throughout the canyon axis. Turbidity on the slope adjacent to the canyons was 10 times lower than inside the canyons. Sedimentation rates and organic matter concentrations in Baltimore canyon were highest under the turbidity plume, whereas in Norfolk canyon sediments organic matter was more evenly distributed with high concentrations throughout the axis. Also sediment grain size distributions differed between canyons; Norfolk canyon had a uniform sediment drape, whereas Baltimore canyon was composed of coarse grained sediments in the upper canyon and finer grained sediments in the mid canyon. The ^{210}Pb measurements show that sediment accumulation rates within both canyons are much higher than on the open slope. In contrast to our expectations, distributions of sediment, sedimentation rates and organic matter differed strongly between both canyons. These differences are attributed to canyon morphology, physical processes and active sediment transport.

DISTRIBUTION AND DIVERSITY OF SCLERACTINIAN HABITATS IN SUBMARINE CANYONS OF THE BAY OF BISCAY (NE ATLANTIC)

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Scleractinian corals in the deep sea may form biogenic habitats, which are seen as functional hotspots. Scleractinian habitats, especially reefs formed by *Lophelia pertusa* and *Madrepora oculata*, can serve as a substrate or a refuge for numerous species as well as spawning-, nursery- and feeding grounds for many fish. However, these reef-building species are susceptible to human activities, such as fisheries, and have slow recovery rates. Due to the vulnerability and functional importance of scleractinian habitats, they are considered as primary target for biodiversity management by a number of international conventions.

In the Northeastern Atlantic, the most well-known habitats formed by scleractinians are large *Lophelia* reefs sitting on carbonate mounds. In the Bay of Biscay, in contrast, scleractinian habitats are mainly co-dominated by the two reef-building species *L. pertusa* and *M. oculata* while two other species, *Enallopsammia rostrata* and *Solenosmilia variabilis*, might be considered as habitat providers as well. In any case, the occurrence of large reefs is rare. These scleractinian habitats are mainly found in association with canyons as patchy reefs, coral rubble or isolated colonies.

In this presentation, we will give an overview of the known distribution of scleractinian habitats in the canyons of the Bay of Biscay. We will consider reefs, coral rubble and isolated colonies, dominated by either *Lophelia/Madrepora, Enallopsammia* or *Solenosmilia*, on both hard as soft substrates and test the influence of habitat characteristics, on the diversity and taxonomic composition of the associated faunal assemblages.

UNDERSTANDING THE HUDSON SUBMARINE CANYON FISHING 'HOTSPOT': THE CONTRIBUTE OF SEAFLOOR MORPHOLOGY, WATER MASS DYNAMIC AND METHANE EMISSION ON MARINE BIODIVERSITY

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The Hudson Canyon, about 180 km SE of New York City, is the largest submarine canyon on the eastern U.S. Atlantic margin and one of the largest of the world, extending for over 400 km from the outer shelf down (~100 m depth) to the upper continental rise (~4000 m). The head of the canyon is recognized to be a fishing 'hot spot' that is inferred to contain essential habitats for several finfish and shellfish stocks and the area is under evaluation to be considered a 'Habitat Area of Particular Concern'. Over the last 10 years many research cruises have been carried out on the canyon area; data collected include: AUV-borne high-resolution bathymetry and backscatter, camera and video surveys, bottom trawls, sediment samples and multi-temporal hydrographic data. These wide-spectrum observations provided the special opportunity to examine the complex interplay among geological, chemical and physical oceanographic conditions of Hudson Canyon and understand the reason of such a fertile habitat. Our study reveals a complexity of geomorphological structures and hydrological patterns within a relatively small area. At the head of the canyon, the presence of gravelly bottom and mudstone outcrops creates the conditions to host rich and varied benthic faunal assemblages including sponges, zoanthids and deep water corals. At greater depth, canyon walls are characterized by a series of ridges perpendicular to the thalweg axis, separated by a dense network of gullies. Within the gullies deep pockmarks lie along the axis while other smaller pockmarks are present as fields in the thalweg. Here, methane anomalies up to 100 nmol L^{-1} were measured in near-bottom water samples. Water column observations highlight a significant inter-annual variability in the structure of the shelf-slope front which may produce strong currents flushing the canyon and distributing nutrients over the Hudson Canyon region. Ultimately, our findings suggest that multiple linked processes between seafloor heterogeneity, water mass regime and methane discharge are driving forces of the biodiversity and biomass production in this ecosystem hotspot.

EXPLORATION OF SUBMARINE CANYONS OFF THE NORTHEAST UNITED STATES REVEALS DYNAMIC HABITATS AND DIVERSE ECOSYSTEMS

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Submarine canyons are some of the most productive, complex features on continental margins worldwide. Numerous deepwater canyons exist on the continental slope off the northeastern United States (NEUS), but this region has been underexplored. During summer 2013, 31 ROV dives were conducted throughout the NEUS canyon system (500–3000 m) to document benthic communities and local geology within the region. More than 40 scientists participated shore-side, in real-time, during the telepresence-enabled expedition. Species composition, richness, and distribution of sessile invertebrates and fishes changed with depth, while differences in abundances within and among canyons were evident and likely driven by local geology. At least 63 coral species (antipatharians, octocorals, and scleractinians) colonized canyon walls, debris fields and soft substrata, with a peak in species richness on canyon walls between 1200–1600 m depth. Coral assemblages observed between 800 and 1450 m were highly similar (>60%), and significantly differed from those found at depths >1700 m. A total of 72 demersal fish species were observed, with species richness generally lower in intercanyon areas and declining with depth within canyons. Fish assemblages also differed between intercanyon and canyon areas and changed across depth (at ~1000, 2000 and 3000 m). Several rarely seen species and species not previously reported from the area were documented, including the fishes *Gaidropsarus argentatus, Guttigadus latifrons, Lepidion lepidion* and the octocoral *Metallogorgia melanotrichos*. The ROV also surveyed four previously unknown chemosynthetic communities, with each supporting classic seep faunal assemblages, dominated by mussels (*Bathymodiolus* sp.), bacterial mats, and methane clathrate was tentatively identified at some sites. Corals were also observed attached to authigenic carbonates associated with these chemosynthetic communities. Exploration revealed that NEUS canyons are both geologically dynamic and biologically diverse, and several canyons have their own geological and biological signature over the examined depth range.

OBJECT BASED IMAGE ANALYSIS OF SIDESCAN SONAR DATA FOR MAPPING SEDIMENTOLOGICAL PATTERNS IN SUBMARINE CANYONS

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Sedimentological patterns and processes are some of the key aspects to the understanding of biodiversity in submarine canyons. Therefore it is crucial to have detailed sedimentological information to produce reliable habitat maps for submarine canyons. However, sediment data grids are often difficult to produce due to a lack of information, resulting from the limited spatial coverage of sediment cores and the high terrain variability in submarine canyons. This study intends to propose a methodology to map out the sedimentological distribution in submarine canyons using sidescan sonar imagery and video interpretation. A combined multibeam and sidescan sonar survey of Whittard Canyon was carried out as part of the EU FP7 project HERMIONE, and the UK OCEANS2025/MAREMAP programme. Within the project CODEMAP, it is now used to create sedimentological data grids for Whittard Canyon using object based image analysis (OBIA) and supervised fuzzy classification. The object based image analysis is used to partition the sidescan sonar data into segments, which are clusters of adjacent pixels that represent meaningful objects on seafloor. These segments are then classified into sediment types, whereby the algorithm is trained using sediments data from video interpretation. The results are evaluated by traditional digitization, based on visual assessment of the sidescan imagery and sediment cores. The segmentation from OBIA allows sedimentological parameters to be estimated from image segments representing meaningful objects and not from individual pixel values, which can be misleading especially for a strongly textured data such as sidescan sonar imagery. The resulting sedimentological map produced contains highly valuable information to be included as an input to produce a habitat map of submarine canyons.

LOCATING HOTSPOTS: MULTI-SCALE ANALYSIS OF BIODIVERSITY WITHIN A SUBMARINE CANYON

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Submarine canyons are complex geomorphological features that have been suggested as potential hotspots for biodiversity. However, few canyons have been mapped at high enough resolution (~10 m pixel size) to investigate questions of scale. In this study, three areas of Whittard Canyon, NE Atlantic, were mapped at fine resolution (1m) using an ROV, while the broader canyon was also mapped at lower resolution (50 m) using a ship-borne multibeam system. The area had also been mapped as part of the Irish National Seabed Survey (INFOMAR) at a third resolution (100 m). Over 100 hours of video were collected along 13 remotely operated vehicle (ROV) video transects at depths ranging from 650 to 4000 m, and used to identify and georeference megabenthic invertebrate species. General additive models (GAMs) were used to build predictive maps for megafaunal biodiversity across a range of scales. The bathymetry-derived environmental descriptors were found to influence biological distributions over a range of scales with variables such as roughness and rugosity providing the most information at finer scales, slope and depth at medium scales and BPI at the broader scales. Vertical walls were found to have the highest diversity of organisms, particularly when colonized by cold-water corals such as *Lophelia pertusa* and *Solenosmilia variabilis*. The spatial biodiversity trends captured remained similar up to 50 m resolution, but coarser resolutions were unable to capture the high habitat heterogeneity and species turnover observed. Based on the maps created, regions of particularly high biodiversity within the canyon were identified and found to represent only a small percentage (~2.5%) of the canyon's surface. The approach developed provides a cost-effective strategy to examine the effect of scale on map creation and facilitate the location of rare biological communities of conservation importance.

GENETIC SURVEYS OF NORTHEAST ATLANTIC SUBMARINE CANYON FAUNA: INITIAL PHYLOGENETIC AND POPULATION GENETIC ASSESSMENTS

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Submarine canyons are among the most productive habitats described in the deep sea and may enhance local and regional species diversity, including those vulnerable to anthropogenic activities. There is now a critical need to delineate accurately faunal diversity for conservation management and protection goals. Toward this end, over the past three years, faunal distribution, abundance, and habitat surveys have been conducted from thirty-seven surveys in Northeast Atlantic Canyons, including Tom's, Hendrickson, Veatch, Gilbert, Ryan, Powell, and Munson Canyons, one minor canyon and two intercanyon areas. We assessed the molecular systematic identification, phylogenetic diversity, and biogeographic patterns of recently collected representative deep-water coral associated communities in Northeast Atlantic Canyons. Specifically, single gene genealogies using mitochondrial COI, 16S, msh1 genes as well as Rad-seq population genetic (single nucleotide polymorphism) data on corals and associated fauna from Powell and Munson canyons were generated and assessed. Results from more than 15 taxa, including scleractinian corals (e.g., *Desmphylum, Solenosmilia*), octocorals (e.g., *Paragorgia*) and their associated fauna, including sponges, polychaetes, ophiuroids, anemones, gastropods, amphipods, shrimp, barnacles, and two species of clams. This genetic information groundtruths extensive imaging surveys conducted, through which community structure is being assessed. The future development of coral-habitat predictive models and habitat suitability maps depends on the confirmation of coral/sponge occurrence data obtained from towed camera surveys, coupled with the genetic identification of recovered specimens. Specifically, these data will be used to: 1) support the NE Regional Deep-Sea Coral and Sponge Initiative; 2) provide guidance to the NEFMC and MAFMC to designate deep-sea coral management alternatives in the northeast and mid-Atlantic; and 3) support the Habitat Blueprint regional initiative in the northeast Atlantic.

BIODIVERSITY OF SUBMARINE CANYONS OF THE SW APPROACHES, UK

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The establishment of a representative network of deep-sea Marine Protected Areas offers one tool with which to address the conservation needs of the deep sea; the challenge now is how to practically implement such networks given our limited understanding of the deep sea ecosystem. Submarine canyons are listed as potential biodiversity hotspots and features that may harbour Vulnerable Marine Ecosystems. In terms of representing habitats within a network of MPAs, it is important to understand differences in species composition and diversity of these megahabitat features.

In 2007, two adjacent submarine canyons (Dangaard and Explorer) and a flank of a third (Irish Canyon) of the SW Approaches, UK were surveyed to characterise the ecology and map the distribution of benthic assemblages. High resolution multibeam echosounder data was acquired over the survey area and 44 image/video ground-truthing acquired. Image samples were quantitatively analysed and all taxa >1 cm identified as distinct Operational Taxonomic Units (OTUs), or morphotypes. Standard multivariate analysis was undertaken (Primer v6) to define distinct faunal assemblages (biotopes).

Twelve biotopes were defined and a number of diversity indices (Simpson's reciprocal Index, rarefaction curves etc.) were used to measure the α diversity of these biotopes. Structurally complex biotopes had the highest Simpson Index (with *Lophelia pertusa* reef having the highest) and soft sediments had the lowest; rarefraction curves also showed *L. pertusa* reefs to have the highest species richness while a seapen (*Kophobelemnon stelliferum*) community had the lowest. Performance of the diversity estimators varied, thus a holistic approach was taken whereby a multivariate diversity indices text was undertaken.

DEEP-SEA MACROFAUNAL ABUNDANCE AND COMMUNITY COMPOSITION IN THE WHITTARD CANYON AND ON THE ADJACENT SLOPE, NE ATLANTIC

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Submarine canyons are important features on many continental margins, where they constitute a major source of seafloor heterogeneity. The question of whether or not benthic communities inhabiting submarine canyons differ from those on the adjacent slope in terms of density and composition is still debated. Furthermore, there is very little information regarding the faunal variation at a single depth within a canyon system. To address these questions we studied benthic macrofaunal abundance, community composition and polychaete species diversity in replicate megacorer samples obtained at three sites in different branches of the Whittard Canyon (NE Atlantic) and one site on the adjacent slope to the west of the canyon. All sites were located at 3500 m water depth.

Macrofaunal abundance decreased from east to west; it was highest in the Eastern branch (6249 individuals m^{-2}) and lowest on the slope (2744 individuals m^{-2}). Overall, polychaetes were the dominant taxon making up >50% of the macrofauna (average density across all sites = 2191 ind m^{-2}), followed by tanaids (10%, 397 ind m^{-2}), isopods (11%, 431 ind m^{-2}), sipunculans (7%, 297 ind m^{-2}) and bivalves (7%, 288 ind m^{-2}). Among the polychaetes, the Amphinomidae were the dominant family (27%, 580 ind m^{-2}), followed by the Spionidae (22%, 480 ind m^{-2}). Assemblage composition changed across the sites. From east to west the proportion of polychaetes and isopods decreased (by 6% in each case), while sipunculans and tanaids increased (by 13% and 8%, respectively). The ranking of the two dominant polychaete families reversed from east to west (Eastern branch - Amphinomidae 36%, Spionidae 21%; Slope – Spionidae 30%, Amphinomidae 10%). The amphinomid *Paramphinome jeffreysii* was particularly abundant in the Eastern branch of the canyon, suggesting a recent recruitment event. Multivariate ordination techniques based on Bray-Curtis similarity of major taxa revealed that the Central and Eastern branches clustered together, as did the Western branch and slope site. This was confirmed by an ANOSIM pairwise test, according to which the Western branch/slope and Central branch/Eastern branch groups displayed the highest similarity while the clearest separation was between the slope and the Eastern branch. Analysis of polychaete species diversity is in progress; preliminary results suggest that there are differences between individual branches and between the branches and the open slope.

In terms of abundance, faunal composition and diversity, differences between the three canyon branches are as great as they are between the canyon sites and the adjacent slope. This probably reflects the influence of organic enrichment together with hydrodynamic activity, both of which are influenced by the characteristics, particularly the topography, of individual canyon branches.

DISTINCT BENTHIC COMMUNITY TRENDS DRIVEN BY AN ENRICHMENT PARADOX IN MID-ATLANTIC BIGHT CANYONS, NW ATLANTIC

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The Mid-Atlantic Bight (MAB) is a well-studied region of the U.S. East coast continental margin, rich in submarine canyons. Baltimore and Norfolk canyons were studied during the multidisciplinary Atlantic Deepwater Canyons project through funding from BOEM, NOAA and USGS. Benthic infaunal community structure, standing stock, species richness and diversity was assessed in the context of canyon environmental parameters and ecosystem ecology. Relating the prevailing canyon environmental parameters to the benthic infauna communities of Baltimore and Norfolk canyons allows for investigations of important factors underpinning canyon ecosystem ecology and eco-functioning of MAB canyons. Benthic infaunal samples were collected by NIOZ box corer in 2012 and 2013 along canyon axes and comparative adjacent slopes, at standardised depths. Fauna were identified to lowest taxonomic unit or assigned putative species and comprised over 400 taxa, the majority represented by polychaetes. The observed nepheloid layer in Baltimore Canyon corresponded to major shifts in infaunal community structure, potentially promoting an enrichment paradox i.e. where increased organic matter delivery creates a heightened sediment oxygen demand, leading to changes in community structure. Significant community shifts were observed in stations at depths >900 m in Baltimore Canyon, coinciding with higher organic matter levels in depths below the nepheloid layer. In contrast, slope communities showed a more uniform infaunal assemblage where distinct zonation patterns by depth were observed. Preliminary data for Norfolk Canyon also show clear differences between canyon and slope benthic communities. Sediment dynamics, organic inputs and disturbance events are clear factors in determining benthic infaunal diversity and standing stock dynamics in and around these canyons.

FISH DISTRIBUTION AND HABITAT USE PATTERNS WITHIN AND NEAR BALTIMORE AND NORFOLK CANYONS, U.S. MIDDLE ATLANTIC COAST

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US middle Atlantic coast submarine canyons support enhanced productivity, diverse and unique habitats and active fisheries but are potentially vulnerable to various anthropogenic disturbances. During two cruises (15 Aug–2 Oct 2012; 30 Apr–27 May 2013), Baltimore and Norfolk canyons and nearby areas were intensively surveyed to determine demersal fish distributions and habitat associations. This presentation treats the fish communities of the deeper (>234 m) areas surveyed. Overall, 25 ROV dives (234–1,612 m) resulted in 239 hrs of bottom video observations and numerous collections. These data were supplemented by 32, 30-min bottom trawl samples. We concentrated analyses on habitat and depth zone association patterns within each study year. General habitat designations were: 1) sand-mud (flat), 2) sloping sand-mud with burrows, 3) low profile gravel, rock, boulder, 4) high profile, rugged canyon walls, rocks or ridges. Two methane seeps (380–430 m; 1,455–1,610 m) added habitats with varying amounts of carbonate rock, dead mussel shells and live mussels. The influence of coral and sponge attached to hard substrata on fish distributions was also investigated.

In total, 125 species of fishes were identified from video and trawl collections, and there were clear habitat and depth patterns. At least 9 fish species are new records for this region. We frequently observed evidence of commercial and recreational fishing activity (lost gear on bottom and fishing boats in the area) throughout the canyons and some resulting habitat damage. Canonical analysis of principal components and Primer (ANOSIM, SIMPER) analyses indicated that in both years, demersal fish assemblages differed by depth of occurrence and habitat type (two-way crossed ANOSIM, R=0.26-0.44, p=0.001). Fish assemblages occurring at depths <500 m were 75% dissimilar from those >500 m, due to the abundance of *Helicolenus dactylopterus* and *Laemonema barbatulum* (shallow) and *Synaphobranchus* spp., *Phycis chesteri*, and *Nezumia bairdii* (deep). In 2013, fish assemblages >1000 m were also significantly different from shallower depths due to the addition of *Dicrolene introniger*, *Lycodes* sp. and *Gaidropsaurus ensis*. Assemblages over sand-mud habitats were significantly different from all other habitats and were dominated by *Synaphobranchus* spp. and *Glyptocephalus cynoglossus* at deeper depths and a variety of species in shallower depths. Interestingly, there was no significant difference in assemblage structure between sloping sand/ mud with burrows and any other habitat, except canyon walls, indicating the burrows may provide enhanced habitat structure. In 2012, fish assemblages at seep habitats (<500 m) with no carbonate rock, but varying degrees of mussel coverage, were significantly different from assemblages in other non-seep habitats due to the abundance of *Lophius americanus, Symphurus nebulosus*, and *Dysommina rugosa* at the seeps. Assemblages on canyon walls were significantly different from most other habitats, except for seep habitats with mixed carbonate and mussel shells. The common canyon wall fishes that drove these differences were *Brosme brosme*, *L. barbatula, Benthocometes robustus*, and *Hoplostethus* spp. Although the presence of corals and sponges did not affect assemblages, there were a few species primarily observed with coral/sponges, including *Anthias* spp. and *B. robustus*.

These two canyons supported abundant and diverse fish communities and exhibited a wide range of habitats, including extensive areas of deep-sea corals and sponges. Many fish species, including economically important taxa, were intimately associated with specific habitats. Conservation measures for the unique and more vulnerable areas (seep and coral habitats) should be considered.

SESSION 4: PHYSICAL & ANTHROPOGENIC DISTURBANCE IN SUBMARINE CANYONS, AND CANYON CONSERVATION

BENTHIC COMMUNITIES OF CANYONS ARE NOT ALWAYS DIFFERENT FROM THOSE AT OTHER DEEP-SEA HABITATS: IMPLICATIONS FOR CANYON CONSERVATION

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Biodiversity studies in the deep sea are often based on single habitat types, such as canyons, seamounts, or abyssal plains. However, deep-sea features are not isolated, and different types of habitat need to be considered as part of a much larger ecosystem. In recent years, research has evolved to address the biodiversity and vulnerability of multiple deep-sea habitats.

Dedicated surveys in two regions off New Zealand have examined continental slope, canyon, seamount, hydrothermal vent, and cold seep habitats, sampling a range of faunal communities from infaunal macrofauna to epibenthic megafauna. Sampling was in four depth strata (700 m, 1000 m, 1200 m, 1500 m) to enable comparisons of faunal change with depth within and between habitats.

Preliminary results indicate that benthic communities of the different habitats are dissimilar but that the level and pattern of dissimilarity varies with the type of community, depth, and region. For example, macro-infauna communities of canyons and slopes were statistically dissimilar to one another at most depths but not at 1000 m. For macro-epifauna, canyon communities were statistically dissimilar from slope and seamount communities in one region but only from slope communities at the two shallowest depth strata in the second region. Hydrothermal vent and seep communities, which include specialised chemosynthetic species, were highly distinct from communities of all other habitats.

The extent of community dissimilarity among habitats, and the life habits and history of the taxa that characterise the communities, are being translated into relative vulnerability profiles to assess the ecological risk posed by human activities, and subsequently to inform improved management of bottom trawling and seabed mining in the New Zealand region. Particular emphasis will be placed in this presentation on the relative vulnerability of canyon communities and the implications for canyon conservation.

MARSHALLING US AGENCY RESOURCES TO INVESTIGATE ATLANTIC SUBMARINE CANYONS

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Exploration and research in and around the U.S. Atlantic submarine canyons was limited during the 1990s and 2000s. In response to emerging science and management drivers for data and information from shelf and slope habitats, the U.S. National Oceanic and Atmospheric Administration (NOAA), federal (e.g., Bureau of Ocean Energy Management, U.S. Geological Survey) and academic partners focused a variety of ship and submersible assets on the Atlantic canyons between 2011 and 2014.

The data and information from more than 23 cruises are providing a wealth of new knowledge to scientists and managers interested in these critical offshore habitats. Over four field seasons, we applied the complementary capabilities of five ships and four submersibles and camera systems to acquire high resolution multibeam data over nearly all of the U.S. Atlantic Canyons and used submersibles to examine the diversity and distribution of deep-sea habitats – including deep coral and seep communities. This presentation will provide a broad overview of United States' coordinated investment in the characterization of the U.S. canyons over the last four years and highlight mechanisms for data access. Though many areas requiring further exploration and research remain, this effort is a model of intra- and interagency coordination that quickly and efficiently gathers baseline information of critical importance to the science and management communities.

RECENT CHANGES ON SEDIMENT ACCUMULATION RATES WITHIN SUBMARINE CANYONS CAUSED BY BOTTOM TRAWLING ACTIVITIES

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The offshore displacement of commercial bottom trawling has raised concerns about the impact of this fishing practice on the deep seafloor. This study focuses on the analysis of sediment accumulation rates from sediment cores collected along the axes of La Fonera (Palamós), Arenys, Besòs and Foix submarine canyons, distributed along the Catalan margin (northwestern Mediterranean), where an intensive bottom trawl fishery has been active during several decades. ^{210}Pb chronology, occasionally supported by ^{137}Cs dating, indicates a rapid increase of sediment accumulation rates since the 1970s, in coincidence with a strong impulse in the industrialization of the trawling fleets of this region. Such increase has been associated to the enhanced delivery of sediment resuspended by trawlers towards the canyon's interior and to the rapid technical development at that time, in terms of engine power and gear size. This change has been observed in La Fonera Canyon at depths greater than 1700 m, while in the other canyons it is restricted to shallower regions (~1000 m in depth) closer to fishing grounds. Two sampling sites from La Fonera and Foix submarine canyons that exhibited high sediment accumulation rates (0.6–0.7 cm/y) were reoccupied several years after the first chronological analyses. These two new cores reveal a second and more rapid increase of sediment accumulation rates in both canyons occurring circa 2002 and accounting for almost 2 cm/y. This second change at the beginning of the XXI century has been attributed to a preferential displacement of the trawling fleet towards fishing grounds surrounding submarine canyons (targeting the priced blue and red deep-sea shrimp *Aristeus antennatus*) and also to technical improvements in trawling vessels, presumably related to subsidies and aids provided by the European Commission to the fishing industry.

BENTHIC FAUNA IN THE SUBMARINE CANYONS OF THE NORTH-WESTERN MEDITERRANEAN SEA

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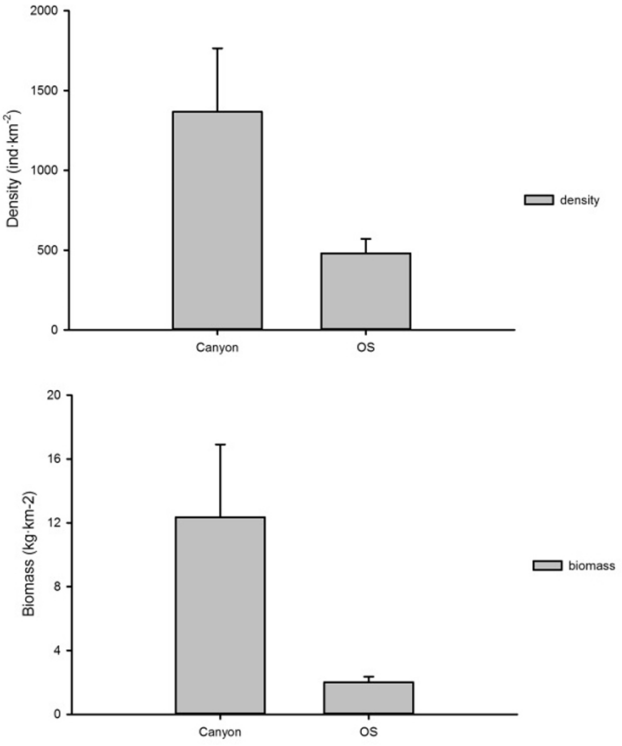
Information of bathyal non-crustacean invertebrates is scarce in the Mediterranean Sea, especially in submarine canyons. The present study reports new data about these bathyal groups inhabiting in deep canyon areas of the north-western Mediterranean Sea. A total of 259 deployments were completed in Blanes, La Fonera and Cap de Creus canyons and the adjacent open slope and, between 850 and 3000 m depth. Samples were realized by means of otter-trawl Maireta system (OTMS), Agassiz trawl, epibenthic sledge and Remote Operated Vehicle (ROV). The density and biomass of non-crustacean invertebrates resulted significantly higher (more than twice) in canyon areas than in surrounding open slope. Two species sampled inside canyon were reported for the first time in the Mediterranean Sea: the carnivore ascidian *Dicopia antirrhinum* C. Monniot, 1972, and the regular echinoid *Gracilechinus elegans* (Düben & Koren, 1844). Both species were observed more than five times, suggesting a large presence which has been largely overlooked in deep Mediterranean canyons. Cold water corals were also detected by ROV as *Desmophyllum dianthus* (Esper, 1794), *Madrepora oculata* Linnaeus, 1758 and *Lophelia pertusa* (Linnaeus, 1758). Finally, large aggregations of the irregular echinoid *Brissopsis lyrifera* (Forbes, 1841) were described. All these data suggested the north-western Mediterranean canyons as hot spots for biodiversity and abundance of resident benthic fauna, and indicate the need for increased sampling effort with new technologies in these ecologically relevant habitats.



MECHANISMS OF OM TRANSPORT AND DEPOSITION WITHIN THE WHITTARD CHANNEL AND POSSIBLE EFFECTS ON THE MEGAFAUNAL COMMUNITIES

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The Whittard Canyon (NE Atlantic) being one of the largest canyon systems on the Celtic margin has a long channel-like extension (Whittard Channel) onto the abyssal plain. The canyon proper receives a relatively high input of organic matter and phytodetritus from the euphotic layer giving rise to dense coral communities on the canyon walls. Little is known about the role of Whittard Canyon as conduit of organic matter to the fan and abyssal plain. To establish if such transport exists we: 1) investigated the distribution of deposit-feeding holothurians and their potential food sources in the Whittard Channel and abyssal plain, and 2) deployed a benthic lander in the canyon for a period of one year to measure transport and deposition rates of organic matter (OM). Camera surveys and boxcore sampling of the Whittard Channel and the adjacent abyssal plain revealed high numbers of elpidiid holothurians and elevated phytopigment concentrations inside the Whittard Channel suggesting that the Channel may act as conduit for OM. The benthic lander in the Whittard Canyon recorded several mass sediment transport events. Analysis of the current direction, concentration and freshness of the organic matter in the sediment however, exclude that these flows supply the fresh organic matter that we found in the Channel. We conclude that the elevated concentration of phytopigments in the Whittard Channel result from local deposition possibly followed by redistribution and accumulation inside the deeper Channel. The mobility of the elpidiid holothurians allows them to exploit these patchy food sources.

THE SUBMARINE CANYON OF PALAMÓS (NW MEDITERRANEAN SEA): A NEW MANAGEMENT STRATEGY BASED IN A PARTICIPATORY PROCESS BETWEEN SCIENCE, FISHERY STAKEHOLDERS, NGOS AND POLICY MAKERS

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A Long Term Management Plan (LTMP) for the fishery of the deep-sea red shrimp *Aristeus antennatus* was officially implemented in the area of the Palamós submarine canyon by the Spanish government in 2013. This shrimp is the main target species for the bottom otter trawling fleet in the whole Mediterranean area. The fishing grounds for this fishery are located at the canyon head and canyon walls of the Palamós submarine canyon (also named La Fonera) one of the largest canyons in the NW Mediterranean Sea. The knowledge from different sectors was merged through a participatory process that leads to the implementation of this LTMP after 4 years of discussions. Fishermen associations, regional and national administrations, scientists and ONG's discussed and integrated their knowledge on the view of the implementation of new management strategies, which includes a reduction of 20% of the fishing effort after 5 years of the implementation of the LTMP and also includes yearly temporal fishing closures during winter months (maximum presence of shrimp juveniles) with no public subventions. All these management measures were integrated in order to reach a sustainable exploitation of this important marine living resource and to improve the health of a highly impacted ecosystem such as are the submarine canyons of the NW Mediterranean Sea.

IMPROVING AND SHARING KNOWLEDGE TO OPTIMIZE MANAGEMENT OF A CROSS BORDER CANYON: THE CASE OF CAPBRETON CANYON (FRANCE, SPAIN)

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The shelf of the southern Bay of Biscay is deeply incised by the Capbreton canyon which begins less than 400 m from the Aquitaine shoreline (France) and extends along the Cantabric coast (Spain). It is influenced by the plume of major French rivers. The canyon's geomorphological and hydrological characteristics favor species diversity and biological production. It contributes to successful reproduction, feeding and nursery functions for many species as hake, mackerel, anchovy etc. Such conditions enhance fishing activities as longliners, netters and trawlers on both sides of the border.

Those various types of fishing in the same space led to adopt different regulations governing access to fishing areas. From this point of view, the French Authority established a restricted area located in the Capbreton canyon; it contributes to a better distribution of the fishing effort. Most of it is under French control, the rest being within the Exclusive Economic Zone (EEZ). The location of such an area in the EEZ raises the question of its legal status, its control, its scientific monitoring and its conservation objectives.

For the time being, different management proposals have been considered by French and Spanish fishermen, but no official agreement at European level has been reached. In 2009, the South Western Waters Regional Advisory Council (SWWRAC) initiated an European Interreg project 'GEPETO' (GEstion de las PEsquerias y Transnacionales Objectivos) in order to achieve a common understanding of the fisheries management in relevant geographic scales and adapted to the specific regional context. Several case studies were selected including a Capbreton case study.

The proposal presents the Capbreton case study and the experience of a 'Co-expertise' project which involves different stakeholders as professionals, scientists, administration and NGOs in all phases of the project. This innovative approach has contributed to enhancing exchanges between stakeholders working together on the same field to optimize management of this cross border area.

PASSIVE ACOUSTIC MONITORING OF CETACEANS AND OBSERVATIONS OF AMBIENT OCEAN NOISE IN THE GULLY MARINE PROTECTED AREA AND ADJACENT AREAS OF THE SCOTIAN SLOPE

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The Gully Marine Protected Area (MPA) is a large submarine canyon located south of Nova Scotia, Canada. It was designated as a Canadian *Oceans Act* MPA in 2004 in part due to the abundance and diversity of cetaceans that occur in the canyon. The core region of the Gully has been identified as critical habitat of Endangered northern bottlenose whales. Other at-risk and rare species such as Sowerby's beaked whales and blue whales are also more frequently observed within the canyon than in other areas off eastern Canada. Investigating the occurrence of cetaceans in the Gully throughout the year has been identified as a research priority for the MPA. Traditionally, most information on whales in the Gully has been collected during summer months due to the difficulties of conducting field studies when weather conditions are more adverse. To fill in this important knowledge gap, two years of near-continuous acoustic data has been collected from the Gully and adjacent slope areas using bottom-mounted Autonomous Multichannel Acoustic Recorders (AMARs, © JASCO Applied Sciences). Initial analysis of the data indicates that many species occur in the Gully throughout the year, including a variety of baleen, beaked and sperm whales and delphinids. In addition, this long-term acoustic data set is being analyzed to establish baseline information on the year-round acoustic environment of the Gully MPA, including natural background ambient noise levels and anthropogenic noise sources, the latter constituting an important potential threat to cetaceans. This presentation will review some preliminary results of the long-term acoustic monitoring study and discuss implications for future research and monitoring efforts within the MPA.

POSTERS

LATE QUATERNARY SEDIMENTARY PROCESSES IN IRISH CANYONS

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The glacially-influenced Irish continental margin demarcates the southern and western extent of the British-Irish Ice Sheet (BIIS). Throughout the mid to late Quaternary, this area has received proglacial sediment from ice that extended to the shelf break from both Ireland and Scotland. Canyon systems on this margin are particularly well developed in front of the glacial end moraines deposited at the ice front. Here the localised delivery of high volumes of meltwater and sediment from the ice front onto the slope likely contributed to canyon incision and the development of canyon depositional lobes. Between 2008 and 2010, three of the canyon systems on the margin were sampled by vibro- and piston-coring. The aim was to better understand the sedimentary processes that occurred on the continental margin during the last glaciation, through the deglaciation and into the Holocene. On the basis of sedimentary structures, texture, grain size, X-radiograph character and physical properties, as well as five radiocarbon dates, eight facies were identified and interpreted in terms of depositional processes as: (1) Massive diamicton deposited as subglacial till close to the shelf break during the last glacial advance; (2–3) Fining upward gravels and sands, related to rise in sea level and changing of hydrographic conditions on the shelf during deglaciation and the Holocene; (4) Laminated muds deposited on the upper slope as plumites during deglaciation; (5) Widespread strucutureless muds representing hemipelagites of Holocene and glacial age; (6) Heavily bioturbated, foraminiferal rich contourites of Holocene and glacial age; (7–8) Coarse- and fine-grained turbidites deposited mainly on the lower slope and trough during the last glacial period. Margin physiography, distance from the ice sheet grounding zone, style of glaciation on the shelf and strength of deep sea circulation are the main controlling factors for these depositional processes.

USING COLD-WATER CORAL MINI-MOUNDS AS ANALOGUE FOR GIANT MOUND GROWTH: ASSESSMENT OF ENVIRONMENTAL DRIVERS AND ANTHROPOGENIC IMPACT

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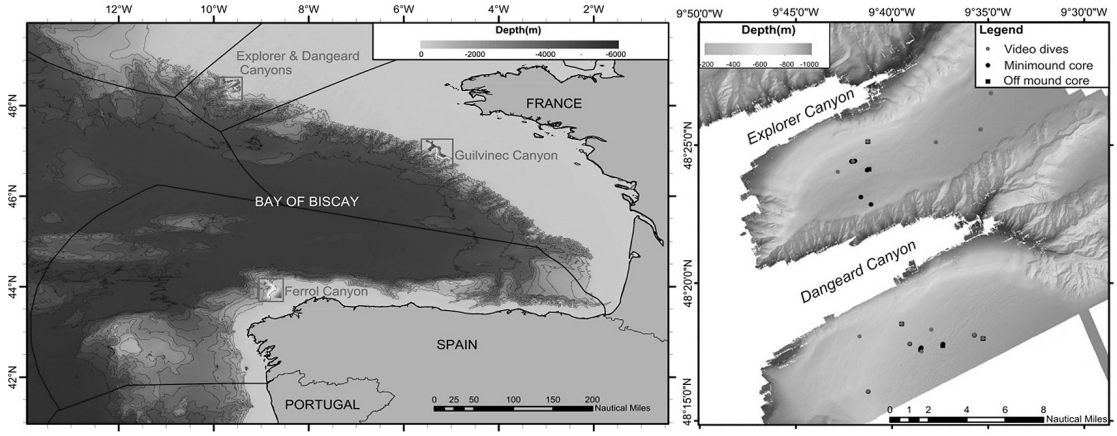
Cold-water corals (CWC) reefs are mainly formed by framework building scleratinians *Lophelia pertusa* and *Madrepora oculata* that baffle sediment and over time, have the potential to develop into large coral carbonate mounds of up to 300 m high (e.g. Challenger mound in the Porcupine Seabight). The detailed mechanisms of initiation and build-up of such large CWC mounds are however not yet fully understood. It is therefore essential to study smaller mounds (often termed "minimounds") that can be interpreted as earlier growth stages that haven't had the time to coalesce and develop into larger mounds. The FWO Minimound project (2013–2016) aims to investigate small fossil CWC mounds within the Bay of Biscay in order to determine the impact of: (1) palaeoceanographic changes related to glacial-interglacial climate change in the last 15 ka, (2) hydrocarbon related processes (seepage) and (3) anthropogenic fishing activities on CWC habitats. The project targets three minimound provinces: the Explorer and Dangeard Canyons, the Guilvinec Canyon and the Upper Ferrol Canyon (Fig.). The Explorer and Dangeard Canyons area has yet been investigated by the RV Belgica Minimound campaign in June 2014. Over 35 m of USBL guided cores were acquired to allow for sedimentological, palaeoceanographic and biogeochemical analyses throughout the minimounds (Fig.). This will be done in cooperation with the BGS (UK), LSCE (Gif-sur-Yvette, France), IFREMER (France), IGME (Spain) and IEO (Spain). In addition, video dropframe acquisition in cooperation with Plymouth University will allow for habitat mapping and predictive modeling of the CWC habitats (Fig.).



Left: Overview of minimound provinces on EMODnet bathymetry map Right: Acquired cores and video data in the Explorer and Dangeard Canyons during the RV Belgica 2014 campaign on MESH 2007 bathymetry map.

CATALOGUING THE DEEP: A PHOTOGRAPHIC ID GUIDE

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The use of photo-imagery as a non-destructive sampling tool in the deep sea is growing, particularly where hard substrata and highly sensitive habitats have become the focus of research attention. Identification of species is often difficult from imagery, especially when lacking specimens, but organisms can be identified as distinct Operational Taxonomic Units (OTUs), or morpho-types. Morpho-species can relate to varying taxonomic levels, from species, family, up to higher taxa. The use of morpho-species allows a greater resolution to be obtained from the data, and can be standardised across research institutes by using standardised terms, or a catalogue. Such a catalogue has been developed by the University of Plymouth for the Rockall Trough region of the NE Atlantic. However, the catalogue is limited in its scope and the web delivery site is extremely basic.

The project is building on the preliminary image catalogue by broadening its scope to include newly collected data from the Bay of Biscay and the western Atlantic, as well as proving a more user friendly web delivery site. The project represents an on-going partnership between Ifremer, NOAA and the University of Plymouth. New image data has been obtained from Ifremer's extensive programme of survey work in the Bay of Biscay and will be supplemented by additional data collected from the Rockall Trough region and imagery acquired by NOAA from the Western Atlantic. Incorporation of these new data represent a significant improvement on the original deep-sea species catalogue as much of these new in situ image data have been ground-truthed through the collection of physical specimens.

In addition to developing the image-based species catalogue, the project aims to further advance the field of using imagery as a sampling tool through providing guidance on species identification from image data, key diagnostic features for specific groups, and advice on dealing with difficult groups such as the sponges. Thus far this element of the project has focused on cold-water corals, but once completed will continue with the other taxonomic groups. These new features will be delivered though a new web based portal that will allow greater interaction between users and data providers.

CHARACTERISING THE DEEP: AN ECOTOXICOLOGICAL PERSPECTIVE

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The deep sea represents the largest ecosystem on earth and is under growing pressure from anthropogenic affects e.g. trawling, mining and exploration for oil and gas. Submarine canyons (SMCs), in particular, may act as conduits, transporting sediment and organic matter from the continental shelf to the deep sea, with canyon heads acting as temporary traps for organic contaminants. Submarine canyons are therefore at risk to increased contaminant burden, as recently observed in the case for marine litter. This proof-of-concept study would allow for i) characterisation of the physiology of deep-sea organisms, in terms of the baseline level of genetic integrity and ii) provide 'Ecosystem Health' assessments: ecotoxicological characterisation of genetic effects of contaminant exposure in vulnerable deep-sea species.

A *'tool box approach'* is proposed and would serve as additive approaches to existing studies, whereby samples collected from partner institutions would be analysed. Assessments would be made from samples stored in various formats: formalin or ethanol fixatives, where biopsied samples from existing museum/storage specimens or recently-collected samples to test the feasibility of these methods and thereby allowing for ease of ship-board sample collection. Employing cost-effective, rapid assessment techniques to evaluate organism health, and thus, a proxy of ecosystem health would enable production of a comprehensive baseline dataset of at risk/vulnerable areas. Wider applicability of this research would be: effects of deep-sea mining, characterising vulnerable marine ecosystems and focussing of survey efforts. As submarine canyons are potentially contaminant *'hot-spots'*, SMC fauna maybe ideal ecological indictors of contaminant exposure.

MORPHOLOGY OF THE SÃO FRANCISCO RIVER CANYON (BRAZIL) AND ADJACENT SLOPE USING MULTIBEAM BATHYMETRY

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Submarine canyons are found on continental margins worldwide and they act as the main conductor of sediments to the deep ocean. Canyon development has been attributed to many causes, especially mass movements, changes in sea level and turbidity currents. The São Francisco canyon, located in the northeastern region of Brazil is directly associated with its homonymous delta. Currently the deltaic clinoform progrades and partially buries the canyon head. Previous studies at the São Francisco delta indicate that during glacial maximums the canyon head deeply indented the shelf and coastal zone, forming a continuum with the alluvial river valley, possibly favored by a shallow shelf break located at 45 m depth. In this work we present the results of a multibeam bathymetric survey recently conducted in the region. It was possible to identify seven major canyons, the biggest one being the São Francisco. It is only at this canyon that available evidences point to a significant role of river discharges on canyon development, such a sinuous geometry of canyon thalweg. Close to the canyon head several terraces boorder the canyon thalweg. The other six canyons were apparently formed by processes of sediment instability and mass movements and exhibit morphologies characteristic of different stages of canyon head erosional retreat. Channel geometries of these canyons varies from 'V' to 'U' shaped ,as a result of different canyon development stagescontrolled by distance from sediment source and infill history. The backscatter values indicate a predominance of muddy sediments throughout the study area. The highest backscatter values occur at the canyon's floor indicating the presence of coarser sediment grain size possibly of bioclastic nature, derived from the outer shelf and shelf break where a carbonate sedimentation dominates. High backscatter values also occur in the walls of the São Francisco canyon, in those segments where erosion processes are important. The slope of the seven canyon varies considerably. The São Francisco canyon is the one with the lowest average values (2° approximately). Other features mapped include a possible São Francisco paleo-canyon, showing a striking morphological similarity with the present canyon (sinuosity and internal terraces). Pockmarks and possible deep-water corals were also identified.

FEEDING HABITS OF DEMERSAL FISHES IN NORFOLK AND BALITMORE CANYONS AND HATTERAS MIDDLE SLOPE

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The continental shelf and slope in the mid-western Atlantic are the subjects of potential oil and gas exploration and wind energy development, support intensive fisheries, and some canyons there have been considered for National Marine Sanctuary designation, yet canyon ecosystems require further study. Submarine canyons are important conduits transporting concentrated organic matter and nutrients into the deep sea while supporting different faunal communities than surrounding areas. For example, the rugged bottom at Hatteras Middle Slope ('The Point') supports the highest densities of benthic fauna anywhere along the U.S. East Coast continental slope and rise. This study focuses on trophodynamics of demersal fishes from Norfolk and Baltimore canyons and The Point canyon system. Gut content analysis is used to elucidate the specific food preferences of the dominant fish species inhabiting these areas.

Fishes from Norfolk and Baltimore canyons were collected in 2012 and 2013, and sampling was conducted at The Point from 1999–2001. The majority of fishes were collected using a bottom trawl, while a smaller number of fishes were colected via ROV or submersible. Gut content analysis was performed for the dominant species collected from the three sites. Stomach fullness was estimated using a scale of 0% (empty), ≤5%, 25%, 50%, 75%, or 100% (full). Stomach contents were quantified using the following indices: abundance of prey species, percent volume of prey, and the percent frequency of occurrence of prey.

Gut content analysis is ongoing and preliminary results (Norfolk and Baltimore canyons only) suggest food items preferred by each species. *Helicolenus dactylopterus* from both Norfolk and Baltimore canyons fed primarily on euphausiids, but also on amphipods and other crustaceans, fishes, polychaetes, and even two insects were injested. *Phycis chesteri* collected from Norfolk Canyon ate mostly decapod shrimp and other crustaceans, polychaetes, and amphipods. Although *P. chesteri* from Baltimore Canyon were poorly preserved, yeilding few viable stomachs, most contained crustacean material. *Lycenchelys verrilli* displayed a varied diet injesting amphipods, copepods, polychates, gastropods, bivalves, and foramaniferans. *Urophycis regia* from both canyons consumed mostly decapod crustaceans, amphipods, fishes, and in Baltimore Canyon cephalopods were also injested. *Coelorinchus coelorhinchus* and *Enchelyopus cimbrius* fed mostly on amphipods, polychaetes, and crustaceans. *Merluccius albidus* ate mostly crustaceans as well as some fishes and sea stars. *Lophius americanus* from Baltimore Canyon (none available from Norfolk Canyon) fed primarily on fishes, squid, and decapod shrimp. *Nezumia bairdii* exhibited a diverse diet including polychaetes, amphipods, bivalves, gastropods, crustaceans, and two insects. *Benthocometes robustus* stomachs contained copepods, euphausiids, and other crustacean material. Most *Dysommina rugosa* stomachs were empty, but those with food included decapod shrimp, euphausiids, amphipods, and isopods. *Synaphobranchus kaupii* consumed euphausiids, decapod shrimp, fishes, and squid.

More active species, like *U. regia* and *S. kaupii*, and those with relatively large mouths, like *H. dactylopterus* and *L. americanus*, ate larger, more active prey. Whereas more sedentary species or those with smaller mouths, like *L. verrilli* and *N. bairdii*, consumed smaller, primarily benthic prey. Predator activity level and mouth size appear to influence feeding habits and determine prey items.

WAS THE 1531 LISBON TSUNAMI GENERATED BY A LANDSLIDE ALONG THE CASCAIS CANYON? PRELIMINARY RESULTS

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In 1531, a 6.5 magnitude earthquake, with an epicentre inland of Lisbon, caused severe damage to the city, rendering a third of its buildings uninhabitable. This earthquake was followed by a destructive tsunami of slightly smaller size than the 1755, although in contrast to the latter it was only observed locally along the entire Tagus estuary and in coastal belt surroundings the mouth of the Tagus River. For the 1531 tsunami, a satisfactory mechanism for its generation has yet to be found, but the inland earthquake epicentre and the absence of large submarine scarps rule out fault-related seabed displacement. An alternative possibility is that the 1531 tsunami was caused by a submarine landslide triggered by the earthquake, producing near-field high amplitude waves close to the source and decaying rapidly with distance. Here we describe a submarine landslide along the Cascais Canyon, whose head faces the Tagus estuary, which may have caused the 1531. At a depth of around 2000 m, up to 150 m across and 45 m high bocks have been imaged over an area of at least 15 km^2 using 30 kHz deep-towed sidescan sonar. Furthermore, erosional furrows and possible gravel waves extending 10 km west of the main block field are seen in sidescan sonar imagery, and seafloor scours extend for ~40 km, suggesting a geologically recent large-scale flow event, which probably involved both a landslide and a turbidity current. High-resolution bathymetry and seafloor photographs acquired at around 4000 m using a remotely operated vehicle (ROV) in the blocky landslide area show boulders at the seafloor, mantled with a thin sediment cover, again suggestive of a recent landslide. Radiocarbon dates from collected cores show that this landslide is likely to have been generated during the 16th century, suggesting a cause-effect relationship with the 1531 earthquake. Preliminary tsunami models suggest that a landslide potentially fitting the characteristics of the Cascais landslide is able to generate a near-field tsunami wave reaching the Lisbon coast but not crossing the whole Tagus estuary, as described in historical documents. Recognising that the 1531 Lisbon tsunami may have been generated by a submarine landslide along a canyon has important implications for understanding geohazards in SW Europe. Our study suggests that small earthquakes with short recurrence periods can generate tsunamigenic submarine landslides, reinforcing the message that hazard analysis must take this threat into account.

MORPHOTECTONICS AND SEDIMENTARY ARCHITECTURE OF DEEP-WATER CANYONS IN THE PEARL RIVER MOUTH BASIN, SOUTH CHINA SEA

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The Pearl River Submarine Canyon system is located in the Pearl River Mouth Basin (PRMB), which is on the northern continental slope of South China Sea and has significant potential for hydrocarbon exploration. The main goal of this study is to constrain the evolution of the Pearl River Submarine Canyon system from the Miocene to the present, and to understand which mechanisms have controlled its evolution through time. Grids of high-resolution 2D multi-channel seismic profiles calibrated using borehole data have been studied to investigate the morphology and sedimentary processes controlling the Pearl River Submarine Canyon system. Results show that two different types of submarine canyon have developed since the Miocene in the Baiyun Sag of PRMB. The Pearl River Submarine Canyon (Type I) can be separated into three segments with different orientations (respectively upper, middle and lower reach). The upper reach is NW-oriented with a shallow incision course, which is characterized by a U-shaped trough and contains several small secondary incisions that represent a present-day deposition-dominated environment and weak mass transportation. However, entering the Baiyun Sag at a water depth about 1,200 m, the canyons course turns E-W, while preserving their U shape. The middle reach narrows and has steeper and asymmetric canyon walls. The lower reach turns to a NW orientation at a depth of 2,300 m, showing a broad, flat and U-shaped trough and flows into the abysmal sea area at a depth of about 3,500 m, and seismic reflections suggest that they are in a stage dominated by long-term deposition. Conversely, the Baiyun Sag northern slope is affected by seventeen sub-parallel modern canyons (Type II), ranging between water depths of ~500 m to 1,700 m. Most of them are orientated NNE-SSW and are about 20–50 km long and 1–7 km wide. The ten canyons in the West reach directly the Pearl River Submarine Canyon, while the other seven in the East converge on the lower continental slope, before finally joining the main course. These deeply cut canyons are V-shaped at the canyon heads and widen to U shapes downstream. In addition, numerous buried channels can be distinguished below the modern northern Baiyun Sag canyons with unidirectionally eastward migrating stacking patterns, implying that these canyons experienced a cyclic evolution with several cutting and filling phases of varying magnitude. A persistent north-eastward traveling bottom current during highstands and turbidity currents during lowstands together shaped the unidirectional development of these buried channels. This evidence suggests that these long established canyons which developed since the Miocene are the main conduits for transporting terrigenous sediment from the continental shelf to the lower slope or abyssal basin during lowstands stage, rather than the upper reach of the Pearl River Submarine Canyon. They have contributed to the formation of vertically stacked deep water fans in the middle reach.

NETWORK ANALYSIS OF SUBMARINE CANYON SEASCAPES – IMPLICATIONS FOR PLANNING AND BIODIVERSITY MANAGEMENT

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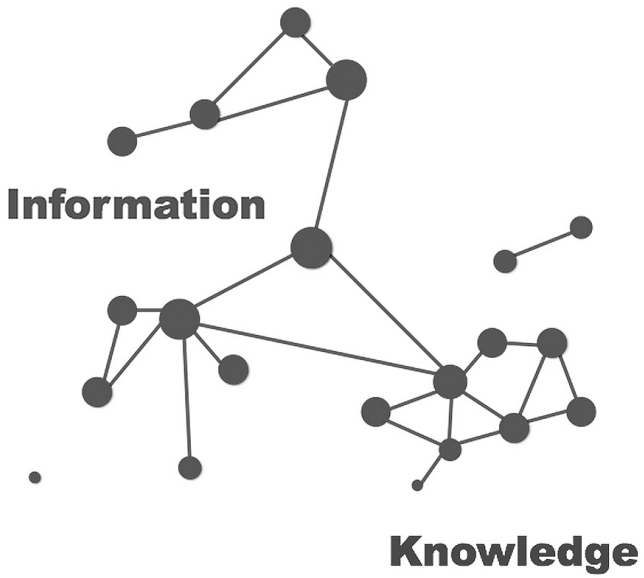
Submarine canyons are distinct geomorphologic structures in the seascape and provide invaluable goods and services for environment and human well-being. The increasing anthropogenic pressure under the canyons ecosystems compromise their health and resilience. Population connectivity and habitat connectedness play a key role in the maintenance of ecosystems' structure and functioning. In this presentation we will introduce a project to study connectivity in submarine canyons using spatially explicit network analysis based on the Graph Theory. Network analyses provide a dynamic perspective of communities' distribution in fragmented habitats. Graphs networks can be used to investigate dispersal pathways and to identify stepping-stones linking distant populations or to infer the presence of dispersal barriers. In this project we propose to synthesize the current knowledge on species and habitat distributions to produce a global perception of their macroecology and connectivity. The knowledge generated by this project will provide scientific evidence to support decision-making in conservation and planning of marine protected areas networks in submarine canyons.



THE GULLY MARINE PROTECTED AREA: TEN YEARS OF SCIENTIFIC RESEARCH AND MANAGEMENT ACHIEVEMENTS TO PROTECT ATLANTIC CANADA'S LARGEST SUBMARINE CANYON

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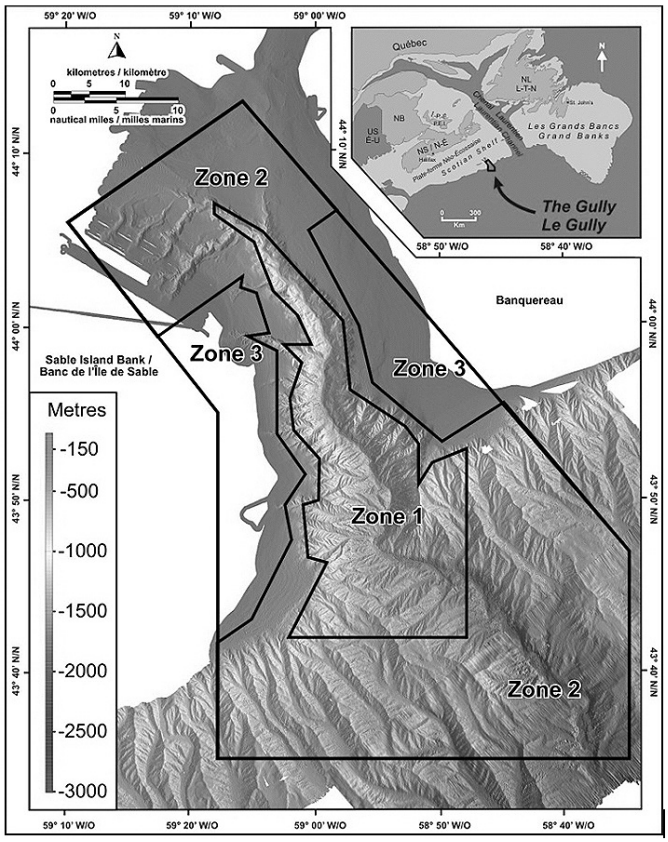
The Gully, a large submarine canyon located south of Nova Scotia, Canada, has long been known as a unique oceanographic feature that is home to an abundance of wildlife. Recognized for its rich biological diversity, the Gully was designated a Marine Protected Area (MPA) under Canada's *Oceans Act* in 2004. Since its MPA designation, much effort has been expended towards accumulating baseline information about the canyon environment and the organisms that reside there, monitoring human activities and their effects on the canyon ecosystem, and protecting the canyon habitat and biota. While managing a deep-water, offshore MPA poses many challenges, the Gully presents a true success story of managers and scientists coming together to conserve of one of Canada's most prized ocean gems. This poster highlights some of the scientific and management accomplishments pertaining to the Gully over the past ten years.



SPATIAL VARIATION OF MEIOFAUNAL ABUNDANCE IN THE BLANES SUBMARINE CANYON ALONG A BATHYMETRIC GRADIENT

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With the aim of improving the knowledge of submarine canyons meiofauna, its abundance distribution and relationship with environmental factors was studied in the Blanes Canyon (NW Mediterranean). Samples were collected during autumn 2012 at six different depths along the canyon axis: 500, 900, 1500, 1750 and 2000 m deep. Two-three replicate corers were taken at each depth with a multicorer, being each corer divided in three sediment layers. Nematoda were always the dominant group (87–95%), followed by Copepoda (2–5%) and Nauplius larvae (1–4%). Average meiofaunal densities (ind. 10 cm^{-2}) ranged from 741 $\pm$ 44 to 1763 $\pm$ 82 at 1500 and 500 m depth, respectively. The highest meiofauna and nematode abundance 1763 $\pm$ 81.5 and 1389.33 $\pm$ 21.6 ind. 10 cm^{-2} occurred in samples from 500) and 1750 m depth. As a general trend, total meiofaunal abundance tended to decrease with depth, but the correlation was not significant (R^2=0.34).The nMDS plot and PERMANOVA results from the meiofaunal assemblages showed significant differences among sediment layers but not among depths. For most of the taxa, the upper sediment layer presented higher abundance than the deeper ones ($p<0.01$). The sediment was mainly fine-grained hemipelagic mud with a high silt content (69 to 77%). The highest sand content (10%) was found at 1200 m deep. PERMANOVA showed that the environmental data significantly differ with depth ($p<0.01$) but not among sediment layers. The highest environmental variability among replicates was found at 1200 m deep. The DISTLM analysis indicates that the contents of Clay, Total Nitrogen and Chlorophyl-a are the variables that most explain the meiofaunal composition ($p<0.05$; 27%, 10% 10% of explained variability respectively). The highest meiofaunal abundance was found at the shallowest station (500 m deep), where the quantity of organic matter (Total Nitrogen, Chlorphyl-*a* and Organic Carbon) were higher and the Clay content was lower than at the deeper sites. This preliminary study showed a noticeably high heterogeneity in meiofaunal abundance among replicates at each depth inside the canyon, which may prevent distinct clear bathymetrical patterns.

ATLANTIC CANYONS — PATHWAYS TO THE ABYSS: A MULTIDISCIPLINARY STUDY OF SUBMARINE CANYONS OFF THE U.S. MIDDLE ATLANTIC COAST

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Growing interest in the ecosystems within numerous submarine canyons along the U.S. middle Atlantic shelf and slope led to this 4-year study funded by the U.S. Bureau of Ocean Energy Management (BOEM), in collaboration with the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey. The project focused on the oceanography, biology, ecology, geology, and archaeology of habitats in and around Baltimore and Norfolk Canyons, emphasizing communities associated with deepsea corals, methane seeps, rugged topography, and shipwrecks. Education and outreach were incorporated throughout the study. The first cruise (4 to 17 June 2011) completed multibeam sonar and CTD surveys of the canyons. A cruise in 2012 was conducted in the Baltimore and Norfolk Canyon areas between 15 August and 2 October. During this cruise, two benthic landers and one mooring were deployed in each canyon, and 30 ROV dives (42 to 1,001 m), 76 CTD stations, 62 box cores, and 15 bottom trawls were completed. Two cruises were conducted in 2013. The first (30 April to 27 May) completed 18 ROV dives (90 to 1,612 m), 34 CTDs, 38 box cores, and 17 bottom trawls. The second and final cruise (21 to 27 August 2013) retrieved the benthic landers and moorings, and completed 22 CTD stations.

Preliminary results and observations made during field surveys include the following:

- Both canyons contained extensive rugged habitats and dense deepsea coral aggregations.
- First mid-Atlantic observations of the corals Lophelia pertusa and Solenosmilia variabilis.
- Octocorals (mainly Paragorgia arborea) were the most common structure-forming cnidaria.
- Among octocorals, genetics revealed 11 sea fan species, 1 soft coral species, and 5 sea pen species, including the first east coast distribution record for one sea fan species.
- Two large methane seeps supported the mussel Bathymodiolus childressi and other abundant fauna.
- 125 species of fishes were identified from deep canyons and 33 species from shelf habitats.
- Sedimentology, organic deposition, and physical processes differed between the two canyons.
- Norfolk Canyon is tenfold more enriched in organic carbon than Baltimore Canyon.
- Baltimore Canyon infaunal communities were less diverse from those on the adjacent slope.
- Ten historically important shipwrecks were found and documented using digital imagery.
- Archaeological integrity of and damage to nine World War I shipwrecks was assessed.
- Project internet blog had >43,000 views worldwide and the internet site was widely used.
- Lost fishing gear and trash were frequently observed on the bottom.

MIXING IN STRATIFIED BOTTOM BOUNDARY LAYERS ON THE STEEP SLOPING WALLS OF UPPER MONTEREY SUBMARINE CANYON

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Strong internal tide generated currents and rough topography lead to intense mixing at the bottom and the sloping sidewalls of Monterey Submarine Canyon. Estimates of mixing were made from measurements with SWIMS3, a depth-cycling towed body, at eleven cross-canyon transects and two along canyon-transects in upper Monterey canyon (at thalweg depths <700 m) over the course of two spring tides and one neap tide. The Gooseneck Ridge and other topographic features in the sinuous canyon acted as roughness elements and hydraulic elements in the baroclinic flow, generating a stratified turbulent bottom boundary layer, similar to that observed by Kunze et al. (2012) elsewhere in the canyon, that was present throughout the measurement region. The cross-canyon transects show a layer of elevated mixing (K>10^(-3) m^2/s) over the canyon bottom, ranging from 70 m thick during neap tide to 300 m thick during spring tide over topographic features. The regions of elevated mixing extend up the canyon sidewalls, diminishing in thickness and magnitude of mixing as the shelf is approached. These sidewall boundary layers generated by the internal tide may be important for sediment re-suspension and other transport processes in the canyon.

SUSPENDED MATTER TRANSPORT AND EPISODIC EVENTS IN WHITTARD CANYON, NE ATLANTIC

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Four research cruises (2011–2014) to the Whittard Canyon have taken place as part of an Irish Bio-discovery and Ecosystem functioning project. Hydrographic observations including turbidity measurements and samples for biogeochemical analysis have been carried in order to improve understanding of biogeochemical cycling and trophic food webs within canyons. Benthic and intermediate nepheloid layers have been detected in four branches of Whittard Canyon in all four years and appear to have a significant impact on the distribution of suspended particulate matter (SPM) in the canyon system. In one of the channels in 2013, a characteristically unusual benthic nepheloid layer was detected with values of an order of magnitude higher than previously observed. Analysis of the SPM has indicated that is it highly degraded organic material, with the exceptionally high concentrations suggesting increased contributions of re-suspended material. The absence of such high values in a repeat transect of the channel in 2014 confirmed that this was an episodic event. Here we present our investigation of the possible sources of the plume, including the possibility of an anthropogenic origin by means of bottom trawling. Such episodic events have significant impacts for the diverse benthic suspension feeding fauna observed here and well as carbon sequestration in the sediments.

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