INCISE

INTERNATIONAL NETWORK FOR SUBMARINE CANYON INVESTIGATION AND SCIENTIFIC EXCHANGE

6th International Symposium

Conference handbook

4th to 8th December 2023

Wellington, New Zealand

NIWA Taihoro Nukurangi
Victoria University of Wellington Te Herenga Waka
AUT Te Wānanga Aronui o Tāmaki Makau Rau

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Welcome to INCISE 2023

Dear INCISE Network and conference participants,

New Zealand's National Institute of Water and Atmospheric Research (NIWA) is proud to host INCISE 2023 as an in-person conference in Wellington. Wellington is not only a vibrant Capital city, but lies at the southern tip of Te Ika-a-Maui, the North Island, with the Cook Strait Canyon System only a few kilometers offshore. The perfect location for the 6th INCISE Symposium.

After a highly successful online event hosted by the university of Gibraltar in 2021 we are really looking forward to being physically in the same space for a week of submarine canyon science!

This year's conference kicks off with a workshop on internal waves and then gets into the >60 presentations spread over 3 days and finishes with a field trip to fossiliferous canyon fill deposits on the stunning Wairarapa coast.

We look forward to meeting you all and hope you enjoy the conference!

Joshu Mountjoy
(INCISE 2023 Convener)

Conference Organising Committe

Joshu Mountjoy – lead convenor (NIWA)
Marta Ribó (AUT)
Daniel Leduc (NIWA)
Ashley Rowden (NIWA)
Katie Maier (NIWA)
Veerle Huvenne (NOC)
Jaime Davies (UP/UniGib)
Robert Hall (UEA)
David Amblas (UB)

Introduction

Submarine canyons are important features along the world's continental margins. They create heterogeneity in the terrain and provide the main pathway for sediment and pollutant transport from the shelf to the deep sea. Although long known, their study has always been a challenge because of their complicated morphology and extreme terrain.

The main goal of the INCISE network is to create a platform for the exchange of ideas and research insights regarding submarine canyons. We do this through several initiatives, including through a regular symposium, organised every other year in different part of the world. We also coordinate a series of working groups focussing on specific questions or topics related to submarine canyons, and creating relevant outputs for science and the wider community.

We are very pleased that we can now have this event in person again. Covid-19 is fading into memory in most places, and there are no longer any restrictions in New Zealand, however we are experiencing an upswing in case numbers and we would appreciate delegates testing for covid if you are experiencing cold and flu like symptoms (e.g. in the morning before coming to the conference). RAT kits can be purchased from most New Zealand pharmacy's.

Housekeeping

We would appreciate it if everyone can upload their talks at the Icebreaker, or at a minimum on the day before they are talking. Links to presentations can be sent to incise2023@gmail.com in advance of the conference.

Poster boards will be available at the Icebreaker and we encourage posters to be put up then or early on the first day (5 Dec) for maximum visibility. Posters need to be removed by lunch time on the 7 Dec at the request of the venue. Poster presenters will have 5 minutes to give a summary of their posters (see schedule).

INCISE has had working groups since 2012 and they have produced many outputs (see INCISE website for more details). During the conference there will be a working group session on 5 Dec and feedback session near the end of the conference on the 7 Dec.

The Venue

The INCISE Workshop, Icebreaker and Conference are all located in Rutherford House, entrance at 33 Bunny Street (-41.279, 174.779, map).

Keynote speakers

Katie Maier
(NIWA)

Tuesday 5th Dec, 09:00h:
Sediment and carbon transfer and sequestration in Kaikōura Canyon, offshore Aotearoa/New Zealand

Dr Katherine L. Maier is a Marine Sedimentologist at the National Institute of Water and Atmospheric Research Taihoro Nukurangi, based in Te Whanganui-a-Tara Wellington, Aotearoa New Zealand. Before coming to Aotearoa, she studied and worked in California, USA, growing an interest in submarine canyons and near-seafloor processes. Much of her research has concentrated on submarine canyons, channels, and their sedimentary dispersal systems offshore tectonically active regions. Her recent work focuses on modern seafloor canyons and their sedimentary deposits in the Kaikōura-Hikurangi system and in the Ross Sea.

Louise Allcock
(University of Galway)

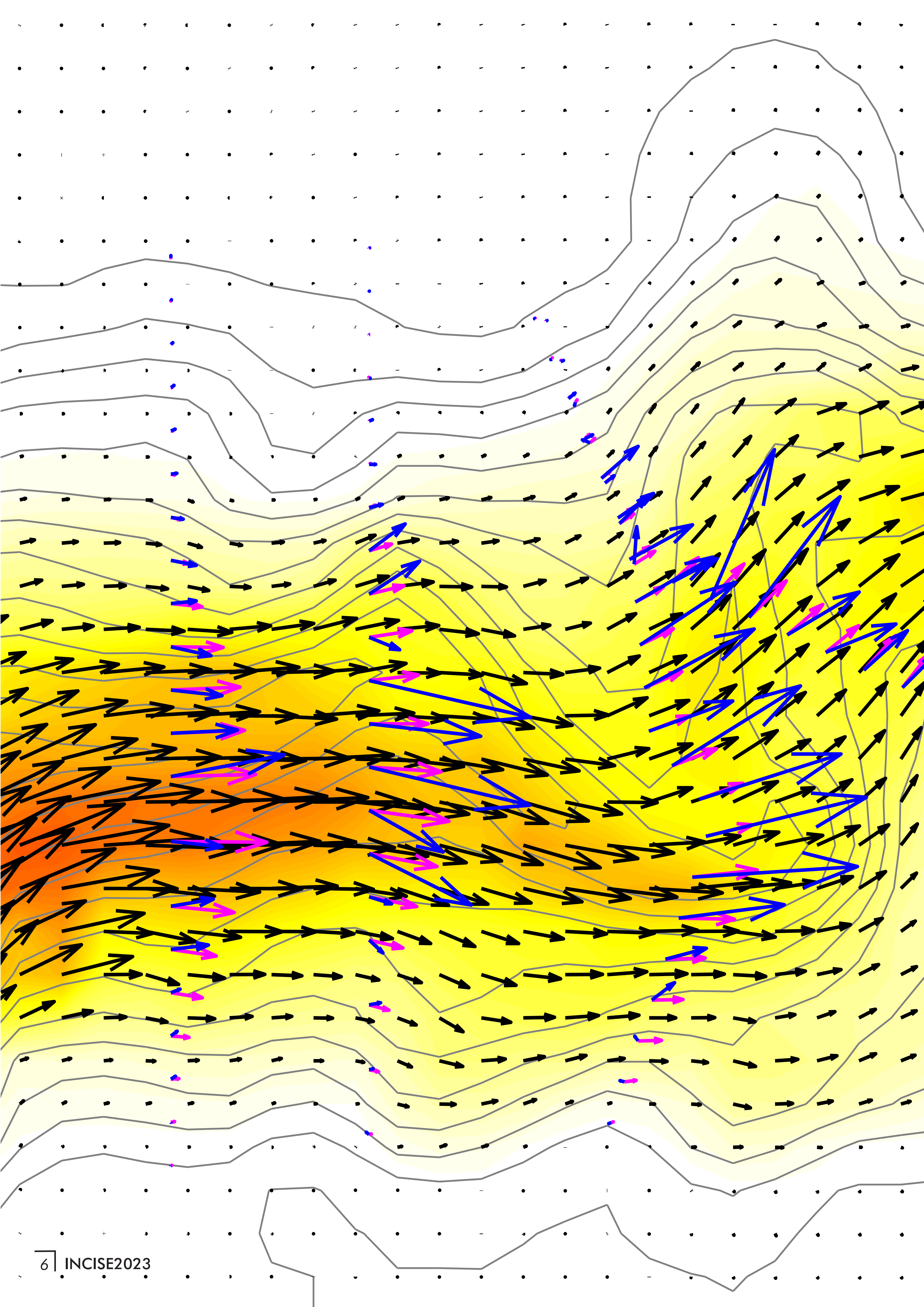
Wednesday 6th Dec, 09:00h:
Exploiting and conserving deep-sea genetic resources – an exploration of biopharmaceutical opportunities in submarine canyons

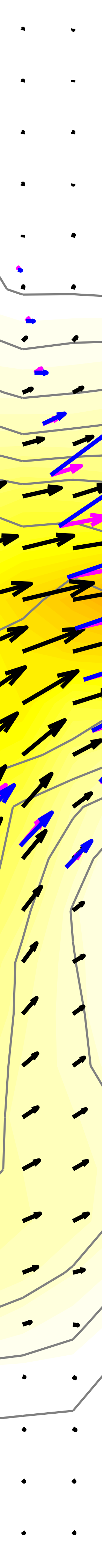
Dr Louise Allcock is Professor of Zoology at University of Galway, Ireland, and a member of the Royal Irish Academy. She has led numerous research expeditions exploring Ireland's extensive submarine canyon systems where her research has focused on systematics and distribution of deep-water corals, and, in collaboration with natural product chemists, the biopharmaceutical potential of these animals. Louise is a member of Ireland's National UN Ocean Decade Committee, and a member of the Ocean Decade's Vision 2030 Working Group 2 'Protect and restore ecosystems and biodiversity'. She chaired, on behalf of Ireland, the Status Assessments of deep-water OSPAR Listed Threatened/Declining VME Habitats working with international experts from across Europe. She currently chairs Ireland's Marine Protected Area (MPA) Advisory Group, providing expert advice to Government on MPA expansion. Louise has co-authored two richly-illustrated books: Octopus, Squid and Cuttlefish (University of Chicago Press, 2018) and The Deep Ocean: Life in the Abyss (Princeton University Press, 2023).

Rob Hall
(University of East Anglia)

Thursday 7th Dec, 09:00h:
Intensified shelf break exchange through submarine canyons: upwelling and internal tides

Dr Rob Hall is an Associate Professor in Physical Oceanography at the University of East Anglia. His research is on shelf sea and deep ocean fluid dynamics, diagnosed from both observations and numerical model simulations. He has a specific interest in internal waves and internal tides, their interactions with complex topography such as submarine canyons, their effect on turbulent mixing, biogeochemical fluxes, sediment resuspension, and their impact on pelagic and benthic ecosystems. As well as conventional ship-borne and mooring observations, he uses autonomous underwater gliders to diagnosis internal wave energetics and turbulent mixing rates.





Monday, December 4

WORKSHOP: Internal waves in submarine canyons

Rutherford House

09:00	**Welcome**	Jaime Davies and Veerle Huvenne
09:10	Internal wave basics	Rob Hall
10:00	**Coffee break**	
10:30	Internal waves in submarine canyons and how to measure them	Rob Hall
11:15	Upper ocean biogeochemical responses to internal tides	Jonathan Sharples
12:00	**Lunch break**	
13:00	Mixing rates from seismic oceanography	Kathy Gunn
13:45	Interaction of internal waves with the seafloor	Marta Ribó
14:30	**Coffee break**	
15:00	Practical session	Rob Hall
16:15	Discussion: Future research into internal wave interactions with the whole submarine canyon system	Lead by Marta Ribó
16:55	Wrap up	Jaime Davies and Veerle Huvenne
17:00	**Close**	

17:00

INCISE Icebreaker

Rutherford House

Programme

Tuesday, December 5

08:00	Registration
08:30	INCISE 2023 Opening

SESSION 1: carbon through canyons (chairs: V. Huvenne, F. de Leo)

09:00	Keynote 1: Katie L. Maier	Sediment and carbon transfer and sequestration in Kaikōura Canyon, offshore Aotearoa/New Zealand
09:30	K. Kiriakoulakis	Controls on Carbon storage in near-surface sediments from the Whittard Canyon, N.E. Atlantic.
09:45	C.C. Tung	Carbon cycling in the benthic food web of a river-connected, higher-energy submarine canyon
10:00	S.D. Nodder	Is organic carbon enriched in submarine canyons around Aotearoa/New Zealand?
10.15	M. Clare	First monitoring in an anoxic deep-sea canyon reveals how powerful river flood- and earthquake-triggered turbidity currents efficiently sequester organic carbon and iron
10:30	**Flash poster presentations** (5′)	
	H. Close	Sorting of sedimentary organic matter along a marginal submarine canyon
	S. Paradis	Global distribution of organic carbon content and age in submarine canyons: results from the “Factors influencing the Accumulation of organic Carbon and its Transfer in Submarine canyons” (FACTS) project.
10:40	**Coffee break**	

SESSION 2: processes shaping canyons (chair: J. Mountjoy, D. Amblas)

11:00	L. Gonçalves de Freitas	New AUV bathymetric data unveils the shaping potential of dense shelf water cascades on the seafloor of Cap de Creus Canyon
11:15	C. Cabrera	Geomorphology and evolution of the Blanes Canyon (NW Mediterranean). New insights from high resolution mapping of vertical cliffs.
11:30	D. Amblas	Simulating the dynamics of Antarctic dense water overflows over complex topographies. A local process with global significance
11:45	S. Ceramicola	Preliminary results from the ERODOTO cruise (EROsive Dynamics Of The squillace submarine canyon), Ionian Sea, Central Mediterranean
12:00	**Flash poster presentations** (5′)	
	G. Carter	An Integrated Approach to Assessing Structural Controls on Canyon Morphology; A Case Study from the Whittard Canyon (Celtic Sea).
	S.J. Watson	The form and history of submarine canyons offshore Taranaki, Aotearoa New Zealand

	S. Bull	Standing on the edge of an exhumed, MTD-filled submarine canyon: the early Pleistocene Castlepoint Formation, eastern Wairarapa, New Zealand.
	L. Gnesko	Upper Kaikōura Canyon: Shaken by de-fault.
	A. Henneker	Understanding gravel transport and bedrock erosion in canyons: Comparison between ancient and present-day submarine canyons
12:30	**Lunch**	
13:30	L. Verweirder	Sculpting a land-detached large-scale canyon-channel system: influence of margin processes before, during and after incision
13:45	M. Pierdomenico	Recent sedimentary processes along submarine canyons of southern Italy: insight from morphobathymetric data and ROV observations
14:00	C. Paull	Assessing the cumulative impact of sediment gravity flows within Monterey Canyon over the last quarter century
14:15	Y.J. Yang	Observation evidences on typhoon-triggered landslide in the submarine canyon.
14:30	R. Gwiazda	Near-Bed Structure of Sediment Gravity Flows Measured by Motion-Sensing Boulder-Like "Benthic Event Detectors" in Monterey Canyon
14:45	**Flash poster presentations (5')**	
	M. Ribo	Insights into understanding how internal waves control the shape of the continental margin
	S.Y.J. Lai	Exploring the evolution of submarine canyon-fan systems in active fault settings: Insights from physical experiments and morphodynamic modeling
	M. Bono	Identification and classification of the Antarctic submarine canyons based on the latest IBCSO Bathymetric Chart v2 and analysis of their oceanographic significance
15:00	**Coffee break**	

SESSION 3: canyon sediment transport (chair: K. Maier)

15:30	P. Puig	Sediment transport mechanisms and downward particle fluxes in Blanes Canyon and their influence on cold water coral benthic communities.
15:45	B.B. Ma	Characterize Acoustic Environment in the Kao-Ping Submarine Canyon – can we the hear the hyperpycnal flows?
16:00	E. Lundsten	Sediment gravity flows independent of submarine channels erode regularly dispersed pockmarks offshore Big Sur, California
16:15	A. Shorrock	Influence of submarine canyons on long-term sedimentation dynamics in the northern Hikurangi Subduction Margin, New Zealand during the late Quaternary
16:30	**Poster session**	
18:00	**Finish**	

Wednesday, December 6

SESSION 4: canyons as havens for biodiversity (chairs: A. Rowden, K. Bigham)

09:15	Keynote 2: Louise Allcock	Exploiting and conserving deep-sea genetic resources – an exploration of biopharmaceutical opportunities in submarine canyons
09:45	R. Hale	Faunal-mediated ecosystem functioning in a benthic deep-sea canyon community recovering from a severe seabed disturbance
10:00	K. Bigham	Resilience of benthic fauna to turbidity flow disturbance in Kaikōura Canyon, New Zealand
10:15	V.A.I. Huvenne	Cold-water coral habitat responses to natural and anthropogenic disturbance: initial results from repeat observations in the Whittard Canyon system
10:30	**Coffee break**	
11:00	A. Parimbelli	Selecting the best framework to model Antipatharia distributions in the Northeast Atlantic deep sea
11:15	C. Lo Iacono	Ecology and hydrodynamic drivers of black coral assemblages in Barkley Canyon, at the core of NE Pacific Oxygen Minimum Zone.
11:30	I. Anell	The Fourth Slope – Curvature analysis of continental margins and the link between shape and processes
11:45	B. Robison	The bathypelagic community of Monterey Canyon
12:00	A. Leitner	Trapped! Sunrise Topographic Blocking of Vertical Migrators at Steep Canyon Walls
12:15	**Flash poster presentations (5')**	
	R. Sherlock	Between a rock and a hard place: when midwater animals bump into the benthos
	M. Bilan	Cold-water coral assemblages along the canyon walls of Blanes Canyon (NW Mediterranean Sea) with notes on vulnerability to increased resuspended sediment
	G.E. Frontin-Rollet	Bringing new life to legacy imagery data: Developing methodologies to enhance geospatial use of legacy Deep Towed Imaging System (DTIS) imagery.
12:30	**Lunch**	

SESSION 5: anthropogenic impacts (chairs: J. Davies, P. Puig)

13:30	J. Davies	Towards standardising reporting of macro-litter (and interactions) in Submarine Canyons to better understand effects of litter on habitats and fauna to aid conservation efforts
13:45	J.P. Xu	How does plastic litters aggregate in submarine canyons? A field scale simulation study
14:00	E. Keavney	Submarine microplastic segregation: bypass and storage in the Whittard Canyon, NE Atlantic
14:15	**Flash poster presentation (5')**	
	M. Pierdomenico	A geoscience perspective on transport mechanisms and global accumulation of litter in submarine canyons
	R. Duran	Assessment of the morphological impact on fishing grounds along canyon flanks using AUV high-resolution side scan sonar and bathymetry
	A. Palanques	Direct and deferred trawling-induced sediment transport events downslope a fishing ground on the flank of Blanes Canyon

14:30 | Coffee break
15:00 | Working groups discussion
16:30 | Poster session
18:00 | Finish

18:30 | **Conference dinner**
The Boatshed (Frank Kitts Park waterfront, -41.288, 174.779)

Thursday, December 7

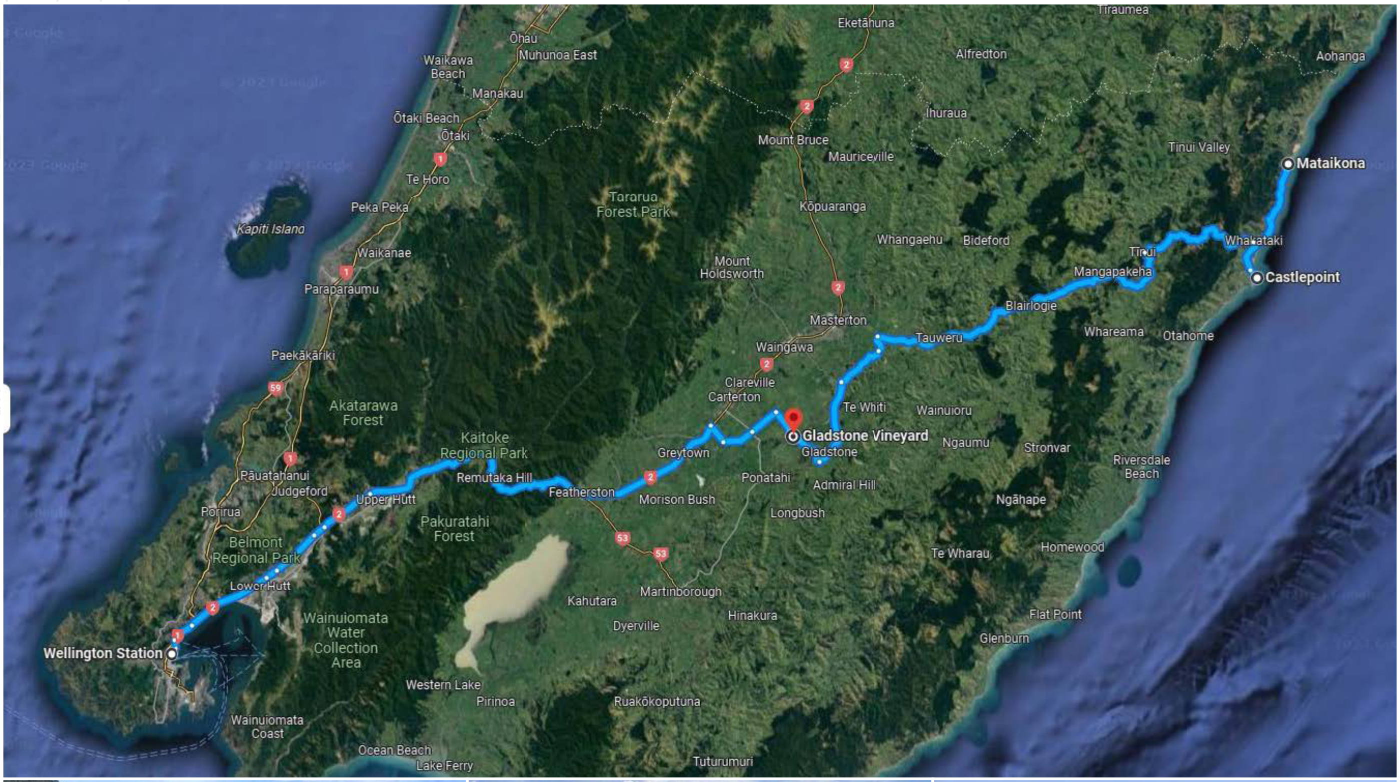
SESSION 6: canyon current dynamics and influence on sediment transport (chairs: M. Ribo, R. Hall)

09:00	**Keynote 3: Rob Hall**	Intensified shelf break exchange through submarine canyons: upwelling and internal tides
09:30	F. Butschek	A Combined Morphological – Oceanographic Investigation of Baroclinic Tides Interacting with the Seabed in a Submarine Canyon
09:45	D. Lyu	Internal tides regulate the sediment dynamic processes in the deep-sea bottom boundary layer
10:00	E. MacDonald	Mapping Spatial and Temporal Variability of Turbidity Within the Whittard Canyon System to Investigate Mechanisms of Sediment Resuspension and the Triggering of Turbidity Currents
10:15	A. Sanchez-Vidal	Assessing the monitoring capacities of CMEMS (Copernicus Marine Environment Monitoring Service) to investigate dense shelf water cascading in submarine canyons of the Gulf of Lions, Western Mediterranean
10:30	**Coffee break**	
11:00	B. Sloyan	Linking East Australian Current dynamics and submarine canyon geomorphology to marine ecosystem hotspots
11:15	W. Ruan	Seasonal Variations of Nonlinear Internal Waves and Sediment Transport in the Northeastern South China Sea
11:30	J.T. Eggenhuisen	Quantifying lateral fluxes of matter down submarine canyons to the deep sea with a simplified process model for turbidity currents.
11:45	M. Yokokawa	Change in subaqueous debris flow and their deposits with or without gravel: an experimental study
12:00	G. Zhong	Morpho-depositional characteristics of a large downstream-narrowing submarine canyon (Xisha Trough) in the South China Sea
12:15	C. Stevens	Observations of the internal tide at the head of Cook Strait Canyon, Aotearoa New Zealand
12:30	**Lunch**	
13:30	S. Li	Submarine canyon morphology along the Chilean marine forearc (19°S-45°S)
13:45	W. Li	The role of sediment gravity flows on the morphological development of a large land-detached submarine canyon (Taiwan Canyon), northeast South China Sea
14:00	**Working groups feedback discussion**	
14:30	**Next INCISE?**	
15:00	**coffee break**	
15:30	**Close of meeting**	

Friday, December 8

Field trip to Wairarapa

The fieldtrip will start at 08:00h at the at the Wellington Railway Station. We will drive over to Castlepoint in the Wairarapa region. First stop will be Mataikona to see deep-sea turbidite beds. Second stop will be at Castlepoint, where we will look at submarine canyon-fill deposits. Return to Wellington via a wine shop or vineyard in Gladstone or Greytown (TBC).



(source: GeoTrips NZ, Whakataki shore platform, J. Thomson, GNS Science)


Abstracts

Simulating the dynamics of Antarctic dense water overflows over complex topographies. A local process with global significance

David Amblas[1], Ricardo Silva Jacinto[2], Joris T. Eggenhuisen[3], Joseph E.A. Storms[4]

[1]Universitat de Barcelona, UB, Barcelona, Catalonia, Spain
[2]Institut Français de Recherche pour l'Exploitation de la Mer, IFREMER, Plouzané, France
[3]Universiteit Utrecht, UU, Utrecht, Netherlands
[4]Technische Universiteit Delft, TUDelft, Delft, Netherlands

In Antarctica Dense Water Overflows (DWOs) are vital for the formation of Antarctic Bottom Water (AABW), the world's ocean densest and coldest water mass and a key piece of the global deep-ocean circulation system. However, the ongoing acceleration in the melting of the Antarctic ice sheet is freshening the dense shelf water, reducing the pumping action of DWOs and thus the volume of AABW. In this scenario submarine canyons gain added significance. Canyons not only facilitate the export of weakened DWOs by steering their flow and enhancing their interaction with the seafloor and surrounding water masses to become AABW, but also foster the penetration of comparatively warmer inflows (i.e. Circumpolar Deep Water, CDW), thus amplifying the basal melt of ice shelves, rising freshwater inputs and reducing and even halting the export of dense shelf water to the deep-ocean.

This study seeks to clarify the intricate connection that exist between DWOs behaviour and bottom friction, sediment entrainment and seafloor topography, with a specific emphasis on submarine canyons and other submarine drainage features. Our strategy involves implementing a depth-integrated, high-resolution numerical model, that integrates realistic physiographic and oceanographic data from the principal contributors of dense shelf water in Antarctica: the Ross and Weddell seas. The findings indicate a significant impact of topography, slope-induced gravity, and Coriolis force on DWO dynamics, a facet that oceanographic models currently fail to adequately capture.

The Fourth Slope – Curvature analysis of continental margins and the link between shape and processes

Ingrid Anell[1]

[1]Department of Geoscience, University of Oslo, Sem Sælands Vei 1, 0371 Oslo, Norway

Clinoforms, developing on varying scales and under different time-frames, are the building blocks of sedimentary geology. The shape can be recognized from cm scale ripples to the kilometre-high slopes connecting the shallow shelves to the deep abyssal ocean floor.

On continental slopes there is a complex interaction between constructive and destructive forces, along with variations in sediment supply, shelf width, water depth, hydrodynamic and depositional processes. To what extent there is a relationship between the shape of slopes, and the processes forming them, is addressed through curve-fitting of over 150 continental margin slopes.

The present study broadens the use of mathematical functions from the previously used three, to improve the potential for prediction of along-strike variations in processes. Four functions are found to closely match most slopes: Linear, Gaussian, exponential and quadratic (positive and negative/inverse). The fourth slope, the quadratic, is by far the most common. While similar to exponential slopes, quadratic slopes actually decrease systematically, which leads to the suggestion that this represents systematic decay of sediment transport with distance. Exponential slopes are instead inferred to result from slope readjustment, with erosion and bypass of the upper slope.

Abrupt shelf-edges are attributed to erosion, given their association with long slope aprons. The smoother Gaussian Sigmoidal slope, appears to represent a more ‘fundamental’ profile. Fairly uncommon are wholly linear slopes, although these are almost always very long and very low angle and probably sites of high sedimentation.

The ability to understand the governing processes, sediment type, rate, and transport mechanisms, influence of antecedent geology, and ensuing slope stability, has wide-stretched economic and environmental implications relating to marine life, resources, climate change and sea-floor infrastructure.

Resilience of benthic fauna to turbidity flow disturbance in Kaikōura Canyon, New Zealand

Bigham, K.T.[1,2], Rowden, A.A.[1,2], Leduc, D.[2] and Bowden, D.A.[2]

[1] School of Biological Science, Victoria University of Wellington, New Zealand,
[2] National Institute of Water and Atmospheric Research (NIWA), New Zealand

A 7.8 (Mw) earthquake triggered a turbidity flow in Kaikōura Canyon in 2016. This event provides a unique opportunity to study the immediate and medium-term influence of large-scale disturbances on the structure of benthic communities in canyons. A time series of seafloor imagery and sediment cores provided data to assess the full benthic fauna community response to the disturbance (mega-, macro-, and meiofauna). The results showed that all faunal size groups had dramatically decreased 10 weeks after the turbidity flow event, and by 4 years after the disturbance the benthic communities were similar to, but not yet the same as, the pre-event communities. The results suggest that while there are strong signs of community recovery the benthic ecosystem functions of Kaikōura Canyon are still yet to be regained. Simple population growth models were used to predict time to full recovery for the community, which was estimated to take between 5 and 10 years, with the macrofauna component projected to take the longest. The percentage of fine sediment and organic matter availability were the main structuring factors identified for the macro- and meiofauna community components, while bioturbation was the main factor correlated with changes in the megafauna community over time. It seems likely that other unmeasured environmental factors, such as sediment oxygen concentrations, are also responsible for the community variation observed in Kaikōura Canyon. Results from this study are synthesised in conceptual models to help better understand the influence of natural disturbances from turbidity flows in canyons and the deep sea.

Cold-water coral assemblages along the canyon walls of Blanes Canyon (NW Mediterranean Sea) with notes on vulnerability to increased resuspended sediment

Bilan, M.[1], Grinyó, J.[2], Gori, A.[3,4], Cabrera, C.[5], Durán, R.[5], Santín, A.[5], Huvenne, V.A.I[6], Lo Iacono, C.[5], Fabri, M.C.[7], Ambroso, S.[3], Piraino, S.[1], **Puig, P.**[5]

[1] University of Salento, Lecce, Italy
[2] NIOZ Royal Netherlands Institute for Sea Research, Den Burg, The Netherlands
[3] Universitat de Barcelona (UB), Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Barcelona, Spain
[4] Institut de Recerca de la Biodiversitat (IRBio), Universitat de Barcelona, Barcelona, Spain
[5] Institut de Ciències del Mar, Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain
[6] Ocean BioGeosciences, National Oceanography Centre, European Way, Southampton, United Kingdom
[7] Ifremer, Centre de Méditerranée, La Seyne sur Mer, France

Submarine canyons are features of the continental margins promoting flourishing deep-sea diversity and abundance. They are characterized by complex topography that intercepts meso-scale ocean circulation, fostering the creation of specific hydrological processes, such as eddies, internal waves and upwelling or downwelling. The topographical and hydrological complexity and substratum heterogeneity, provide good conditions for cold-water coral (CWC) growth.

The NW Mediterranean continental margin is densely incised by submarine canyons where the Levantine Intermediate Water (LIW), considered the main path of CWC distribution in the Mediterranean, flows at intermediate depths (300-600 m). Several submarine canyons in the NW Mediterranean are recognized as important CWC habitats, where the dominant species is the scleractinian Madrepora oculata. The shelf-incising 184 km long Blanes Canyon is one of the most conspicuous canyons of this sector, found on the Catalan margin and located only 4 km from the coast. The Blanes Canyon is surrounded by important fishing grounds for many species of commercial interest, including the blue and red deep-sea shrimp Aristeus antennatus. Fishing grounds are located on the canyon flanks and rims, as well as one fishing ground passing through the canyon axis. Bottom trawling causes sediment resuspension on the fishing grounds, which is transported downslope in forms of nepheloid layers or diluted sediment gravity flows and have a negative impact on the suspension feeding organisms living on the canyon walls.

The Blanes Canyon has been studied from oceanographic and geological points, but the extent of CWCs within the canyon was still uncertain. This study provides a detailed description of megabenthic assemblages found in the canyon head and east canyon flank tributary. The most abundant animal group found were CWCs, with colonial scleractinians found along the canyon head while octocorals and black corals were the major contributors in the east canyon flank tributary. Potential reasons for this geographic separation of CWCs seems to be related to vulnerabilities of selected coral species to increased suspended sediment concentration originating from sediment transport processes, including the effects of bottom trawling resuspension.

Identification and classification of the Antarctic submarine canyons based on the latest IBCSO Bathymetryc Chart v2 and analysis of their oceanographic significance

Marta Bono[1], **David Amblas**[1], Riccardo Arosio[2]

[1] Universitat de Barcelona, Barcelona, Catalonia, Spain
[2] University College Cork, Cork, Ireland

Submarine canyons are deep, large-scale incisions that occur on the continental shelf and slope of all ocean margins. These canyons play a crucial role in the formation of Antarctic Bottom Water (AABW) as they allow dense, nutrient-rich waters confined to the Antarctic continental shelf to travel into the abyssal zone of the ocean. These dense waters contribute greatly to the global deep circulation, which is vital for the transport of heat and nutrients across the oceans.

Currently a warming trend has been detected in the deep ocean at high southern latitudes, with some studies indicating that the inflow of meltwater around Antarctica leads to a contraction of the AABW, opening a pathway that grants the warm Circumpolar Deep Water (CDW) access onto the continental shelf. A good understanding of the extent and distribution of submarine canyons around Antarctica is therefore needed.

This study aimed to create the best possible catalogue of Antarctic submarine canyons. Mapping was conducted taking advantage of the new International Bathymetric Chart of the Southern Ocean (IBSCO v.2) and using ArcGIS Pro 3.0.4 software. The study area was subdivided into ten zones and the geomorphological variations between them were analysed. Semiautomatic hydrological techniques were adopted to delineate the drainage network, and to extract useful attributes such as the order structure of the submarine canyons and the longitudinal profile of the main thalweg.

A total of 308 drainage networks were identified, with 3256 currents. The East Antarctica's areas are the ones that have more complex and large drainage networks, up to an order of Strahler 5. The Antarctic Peninsula is one of the areas with the most drainages (n=110), although its submarine canyons have lower orders and lengths. Conversely, the primary formation of AABW is in the Ross and Weddell seas, characterized by fewer canyons of relatively greater length. The areas of Western Antarctica have a relatively complex complexity, although their length is similar and relatively shorter than in the East Antarctica. Regarding the main drainage courses, most submarine canyons identified have a concave profile, except in Eastern Antarctica 1, where convex trends were observed.

Standing on the edge of an exhumed, MTD-filled submarine canyon: the early Pleistocene Castlepoint Formation, eastern Wairarapa, New Zealand

Suzanne Bull[1], Kyle Bland[1], Dominic Strogen[1], Malcolm Arnot[1], Andrew Boyes[1], Jess Hillman[1]

[1] GNS Science, Lower Hutt, Wellington New Zealand

Mass transport deposits (MTDs) have been shown to be concentrated within submarine canyons from the modern seafloor of eastern New Zealand. We present early results from a new field-based outcrop study of the Castlepoint Formation, eastern Wairarapa. The rocks of Castlepoint Reef, and the famous local landmark Castle Rock, have been dated to the early Nukumaruan (~2.4 Ma) and interpreted as a submarine canyon head filled with several mass transport deposits (MTDs) based on fossil assemblages. This study aims to define the overall architecture of the canyon and high-resolution stratigraphic sequence of its fill. The canyon walls are interpreted from steeply dipping, sharp contacts between soft blue-grey mudstones of host Rangiwhakaoma Formation and the shelly limestones and calcareous sandstone of the Castlepoint Formation, which comprises the fill. Five MTD units, originating in shallower water and transported down the canyon have been identified. Sedimentary structures include fluid release structures and large load casts. Large, deformed blocks of mudstone within the canyon fill indicate deformation and collapse of the canyon walls. We anticipate that results of the mm-scale, high resolution stratigraphic analysis will provide an analogue for modern New Zealand submarine canyons, with implications for canyon evolution, MTD-canyon interactions and the internal organisation of complex, multi-phase canyon filling MTDs.

A Combined Morphological – Oceanographic Investigation of Baroclinic Tides Interacting with the Seabed in a Submarine Canyon

Felix Butschek[1,2], Riccardo Arosio[1], Aaron Lim[2,3], Andrew J Wheeler[1,2,4]

[1] School of Biological, Earth & Environmental Sciences, University College Cork (UCC), Ireland
[2] MaREI, the SFI Research Centre for Energy, Climate and Marine, Environmental Research Institute, UCC, Ireland
[3] Department of Geography, University College Cork, Ireland
[4] iCRAG, the SFI Research Centre for Research in Applied Geosciences, UCC, Ireland

Baroclinic tides are common forms of internal gravity waves in submarine canyons, which have a focusing effect on such internal waves. Internal gravity waves have been described as a key vector for energy transfer into the deep ocean, and submarine canyons represent conduits for the transport of sediments and organic matter from shelf to deep seas. This combination makes shelf incisions key features for oceanographic, sedimentary and biological processes. The breaking of internal waves increases turbulence & mixing, converts potential to kinetic energy, intensifying currents and thus resuspending sediments. Whether this process occurs is governed by the wave's angular velocity, latitude, slope of the seabed and Brunt-Vaisala frequency N^2 — a stratification-dependent seawater property that describes the restoring force acting on internal waves.

In this study, an array of seven Acoustic Current Doppler Profilers (ADCPs), 38 CTD casts and 25-m resolution bathymetry are used to identify and map natural seabed features that form breakwaters for internal waves at various tidal frequencies in the upper Porcupine Bank Canyon (PBC), west of Ireland. N^2 data is highly sensitive to minute changes in temperature and salinity, within the measuring error of commonly used instruments. Thus, an a-priori statistical framework was developed to identify trends and eliminate noise. These data were used to compute bootstrap estimates and confidence intervals of N^2 at the seabed and consequently calculate if internal waves are likely to break in the upper PBC.

While patterns in the breaking zone for semidiurnal (M2) tides are elusive, shallow water lunar overtides (M4/M6) are likely to break or form through frequency doubling at the base of cold-water coral mounds and ridges in the upper PBC. Periodograms of current speed and acoustic backscatter from ADCPs are also statistically significant at the period of M4 & M6 tidal constituents. These findings attribute greater importance than previously thought to higher-frequency tidal constituents, which may affect benthic boundary layer processes and coral mound evolution.

Geomorphology and evolution of the Blanes Canyon (NW Mediterranean). New insights from high resolution mapping of vertical cliffs

Cabrera, C.[1], Durán, R.[1], Puig, P.[1], Fabri, M-C.[2], Guerin, C.[3], Lo Iacono, C.[1], Huvenne, V.A.I.[4]

[1] Institut de Ciències del Mar, Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain.
[2] Institut français de recherche pour l'exploitation de la mer (Ifremer), Centre de Méditerranée, La Seyne sur Mer, France.
[3] Institut français de recherche pour l'exploitation de la mer (Ifremer), Centre de Bretagne, Plouzané, France.
[4] Ocean BioGeosciences, National Oceanography Centre (NOC), Southampton, United Kingdom.

The geomorphology of the Blanes submarine canyon has been characterized based on the analysis of high- and very-high resolution hull-mounted multibeam bathymetry (up to 5 m grid size) collected from the canyon head to the mid canyon. Additionally, the Hybrid Remotely Operated Vehicle (H-ROV) Ariane was used to map with unprecedented detail (80 cm grid size) the morphology of sectors of the canyon with vertical rocky walls. High-resolution video footage was also acquired on the same canyon walls with the ROV Liropus. The Blanes Canyon exposes highly stratified Mio-Pliocene successions dipping towards a SW direction, which have also been identified on the outcrops of the continental shelf and slope of the northern Catalan margin (Western Mediterranean). These successions are affected by the presence of NE-SW and NW-SE oriented ancient fault systems, which have played an important role in the development of the Blanes Canyon. The structural character of the canyon is evidenced by the rectilinear trajectories and sharp bends of the canyon axis and rims, the alignment of pockmark fields and by the presence of vertical rocky walls that can reach up 300 m in height. The canyon transversal profile is asymmetric due to the underlying stratigraphy. It shows a smooth eastern flank mainly dominated by landslides and toe gullies in its cataclinal slope, which is characterized by strata beds dipping in the same direction of the slope. A steeper western flank is dominated by a dendritic network of rim gullies in its anaclinal slope, facing opposite to the dip of the strata. H-ROV bathymetric maps of vertical cliffs display a wide variety of small-scale morphological elements, evidencing ongoing mass wasting and gully development. As at canyon scale, these are the main mechanisms in wall retreatment, mainly resulting in falling blocks on cataclinal slopes, and rills and emerging gullies on steep slopes. The multi-scale study of the Blanes Canyon has allowed a better characterization of the erosive processes occurring on its walls, thus contributing to the understanding of the evolution trough time and space of submarine canyons developing in tectonically controlled stratigraphic bedded sequences.

An Integrated Approach to Assessing Structural Controls on Canyon Morphology; A Case Study from the Whittard Canyon (Celtic Sea).

Gareth Carter[1], Silvia Ceramicola[2], Veerle Huvenne[3], Esther Sumner[4], and all members of the JC237 Research Cruise

[1] British Geological Survey, Lyell Centre, Research Avenue South, Edinburgh, UK
[2] OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy
[3] Ocean BioGeosciences, National Oceanography Centre (NOC), Southampton, UK
[4] School of Ocean and Earth Sciences, University of Southampton, Southampton, UK

Many studies to date have focused on submarine canyon morphology with an emphasis on unconsolidated, unlithified sediments and how they influence the geometries and shapes of submarine slopes. However, the underlying lithostratigraphic framework of the margin into which each canyon is incised has, traditionally, received much less attention. This is, in part, due to the challenges posed by the extreme, and often deep-water, settings of submarine canyons. Deep-water settings prohibit the collection of hull-mounted high-resolution (<10 m gridded) multibeam bathymetry, whilst the steep-sided rock walls pose restrictions on collecting useable sub-bottom (seismic) data along the slopes. In addition, acquiring ground-truthing data (e.g., material samples) from steep rock walls is incredibly challenging, which in turn limits our ability to produce detailed geological models of canyon systems themselves. Such models can have cross-disciplinary applications, from understanding potential substrate distributions for the colonisation of benthic/sessile communities to identifying potential geohazards (e.g., slope collapses) along the canyon flanks.

Here, we propose adopting a data-integration approach to assessing the structural framework into which shelf-incising canyons commonly incise, using Whittard Canyon as a case study. Whilst structural evidence of large-scale (km-length) fault systems can be gleaned from coarser hull-mounted multibeam echo sounder (MBES) data, we demonstrate that by nesting gridded MBES datasets of higher resolution (metre-scale, acquired from AUV-mounted MBES) within the lower-resolution data can allow us to assess structural controls on canyon morphology at an individual branch scale. This includes assessing how tectonic controls may influence changes in thalweg orientation and, therefore, the overall sinuosity of the canyon branch. In addition, to overcome the issue of poor seismic data quality along steep canyon slopes, we combine AUV-based sub-bottom data with visual observations from ROV transects of slopes to ascertain depths at which lithological and morphological (e.g., breaks in slopes) changes appear to take place. This evidence is augmented with ground-truthing data (e.g., rock samples, including drilled core plugs to estimate lithology and rock strength) to support the proposed methodology for ultimately making an interpretation of the lithostratigraphic framework into which the Whittard Canyon is incised, and conversely how these structural controls may influence canyon morphology.

Preliminary results from the ERODOTO cruise (EROsive Dynamics Of The squillace submarine canyon), Ionian Sea, Central Mediterranean

Silvia Ceramicola[1], Veerle Huvenne[2], Nora Markezic[1,3], Marco Bianchini[1,4], Denise Petronelli[4], Kobus Langedock[5], Fred Fourie[5], Tiago Alves[6], Joannis Morfis[7], Mitja Jankovic[8] and all members of the ERODOTO Cruise

[1] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale OGS, Italy
[2] National Oceanography Centre, (NOC), Southampton, UK
[3] Dipartimento di Matematica e Geoscienze, Università degli Studi di Trieste, Italy
[4] Dipartimento di Scienze della Terra, Sapienza Università di Roma, Italy
[5] Flanders Marine Institute, VLIZ; Ostend, Belgium
[6] 3D Seismic Lab - School of Earth and Environmental Sciences, Cardiff University, UK
[7] Institute of Oceanography, HCMR, Athens, Greece
[8] NOVA Grafica, via Giuseppe Mazzini 30, Trieste, Italy

The ERODOTO Cruise, funded by the Eurofleets+ programme, took place last July 2023 in the Ionian Sea onboard of the Greek research vessel Aegaeo. The cruise aimed to analyze and quantify the active dynamics of the shelf-incising, close-to-shore Squillace submarine canyon (Calabrian margin) as a model for geohazards assessment and risk management. Squillace Canyon has a close connection to ephemeral river systems regionally known as 'fiumare'.
The cruise had four specific objectives:

1. Detailed documentation of canyon head morphologies, particularly of the geomorphological indicators of imminent/incipient sediment failure (e.g.,cracks, developing scarps, creep …) and related deposits (e.g., blocks, pebbles, slab slides …)
Approach: detailed high-resolution acoustic mapping using the VLIZ Gavia AUV (sub-metre scale). This was intended as the initiation of a monitoring programme that can be continued in the future by local authorities, potentially with AUV launch from shore.

2. Quantification of the dynamics of sediment flows in the combined fiumare-canyon system
Approach: specific cores for grainsize analysis, bedform morphological analysis, sediment dynamic modelling, mapping of the connection between fiumare on land and the underwater headwalls under investigation.

3. Assessment of the geotechnical properties of the shelf sedimentary sequences incised by the headwalls: shear strength, cohesion, consolidation, etc.
Approach: sediment strength/ geotechnical measurements on sediment cores, visual observations of canyon wall morphology and sediment type using the HCMR ROV Max Rover, and sediment stability modelling

4. Development of a blueprint for coastal hazard assessment and monitoring in proximity to submarine canyon heads:
Approach: the ERODOTO cruise provided a pilot study demonstrating the a methodology for semi-autonomous hazard monitoring in shallow coastal areas adjacent to submarine canyon heads, under the influence of suspected retrogressive erosion induced by recurrent sediment flows.
In this work we will present some of the initial results of the ERODOTO cruise and discuss lessons learnt for future monitoring surveys in the area.

First monitoring in an anoxic deep-sea canyon reveals how powerful river flood- and earthquake-triggered turbidity currents efficiently sequester organic carbon and iron

Mike Clare[1], Anna Lichtschlag[1], Hal Himsworth[2], Philip Banks[2], Liz James[2], Andrew Gates[1]

[1] National Oceanography Centre (NOC), Southampton, United Kingdom
[2] Subsea7, United Kingdom

Submarine canyons are the primary link between continental shelves and the deep sea, providing conduits for the transfer of globally-significant quantities of both natural and anthropogenic particulate material. This connection is particularly important offshore from rivers that convey large volumes of terrestrially-derived material, including fresh organic carbon and pollutants. Dense underflows of sediment called turbidity currents are the primary mechanism by which particulate material is transported along submarine canyons. While advances in technology have provided new insights into the behaviour of these flows, there remain remarkably few observations that capture the precise timing of turbidity currents to identify different triggering mechanisms and understand the implications for deep sea particulate fluxes. Here, based on detailed monitoring datasets from a canyon system in the south-western Black Sea, we show how two major external events triggered powerful turbidity currents that were capable of transporting heavy (0.6 tonne) seafloor frames. A large river flood, that resulted from 150 times the normal rainfall, discharged a sediment-laden plume that plunged into multiple canyon heads synchronously, creating a turbidity current that ignited as it entrained seafloor sediment. Five months later, a magnitude 6.1 earthquake (in the upper 0.5% of historically-recorded quakes regionally) triggered an even more powerful flow, this time remobilising canyon flank sediments that were likely emplaced following the flood. These two events had distinct depositional fingerprints and provide new insights into particulate transport along submarine canyons. The direct delivery of river flood-derived material to the submarine canyon head ensured that highly-reactive organic carbon and iron could bypass a shallow oxic layer, and transferred to anoxic waters, becoming buried rapidly in the deep-sea canyon. Earthquake-induced seafloor remobilisation then shuffled previously-deposited sediments into deeper water, however, in contrast to open ocean settings, the anoxic bottom waters of the enclosed Black Sea ensure that the carbon and iron remain effectively sequestered.

Organic and isotopic indicators for sorting of sedimentary organic matter along a marginal submarine canyon

Hilary G. Close[1] Matthew D. McCarthy[2], **Nancy G. Prouty**[3]

[1] University of Miami, Rosenstiel School of Marine, Atmospheric, and Earth Sciences, Miami, FL 33149
[2] U.S. Geological Surve, Pacific Coastal and Marine Science Center, Santa Cruz, CA 95060
[3] Ocean Science Department, University of California, Santa Cruz, Santa Cruz, CA 95060

Submarine canyons are incised features of many continental margins that can have significant influence on the hydrodynamic distribution of sediments and organic matter eroded and deposited from the continents. Baltimore Canyon, on the U.S. mid-Atlantic margin, contains a complex set of sedimentary processes that simultaneously create unique benthic habitats and control the deposition of organic matter. Along the canyon axis, loci of net erosion, net deposition, and intense winnowing each host diverse faunal assemblages and varying mixtures of sedimentary organic matter derived both from production in the overlying water column and from mobilized sediments. Bioavailable components of this deposited organic matter sustain benthic communities, while recalcitrant components can contribute to long-term carbon burial in the deep sea. Here we probe in detail the terrestrial versus marine origins of organic matter along a transect in Baltimore Canyon, as well as its bioavailability for benthic fauna, in order to explore how canyon-specific sediment dynamics might emplace a functional sorting of organic matter from shelf to open ocean. We present a novel approach to separate functional classes of organic matter and investigate sources and degradative pathways of organic matter in Baltimore Canyon. In combination with bulk geochemical characteristics, surface sediments from water depths of ~200 1200 m were sequentially extracted to separate nonpolar and polar lipid classes, an acid-hydrolysable fraction, and a non-hydrolysable fraction. Each class was analyzed for carbon and nitrogen quantities, stable isotope ratios, and radiocarbon content where possible, along with isotopic indicators derived from individual amino acids in the hydrolysed fraction. Our results highlight differences in provenance and bioavailability of organic matter along the canyon, which correlate to grain size and erosion/deposition dynamics. In addition, we suggest that a relatively simple determination of the concentration of hydrolysable organic matter may provide better information about the nutritional quality of sediments for benthic fauna compared to bulk carbon or nitrogen concentrations.

Towards standardising reporting of macro-litter (and interactions) in Submarine Canyons to better understand effects of litter on habitats and fauna to aid conservation efforts

Jaime S Davies[1,2], Ivan Hernandez[3], Alice L Bruemmer[1], Veerle Huvenne[4], Awantha Dissanayake[1]

[1] School of Marine and Environmental Science, University of Gibraltar, Gibraltar
[2] MBERC, University of Plymouth, UK
[3] Laboratory of Maritime Engineering, Universitat Politècnica de Catalunya, Spain
[4] National Oceanography Centre, Southampton, UK

Submarine canyons are incised features of many continental margins that can have significant influence on the hydrodynamic distribution of sediments and organic matter eroded and deposited from the continents. Baltimore Canyon, on the U.S. mid-Atlantic margin, contains a complex set of sedimentary processes that simultaneously create unique benthic habitats and control the deposition of organic matter. Along the canyon axis, loci of net erosion, net deposition, and intense winnowing each host diverse faunal assemblages and varying mixtures of sedimentary organic matter derived both from production in the overlying water column and from mobilized sediments. Bioavailable components of this deposited organic matter sustain benthic communities, while recalcitrant components can contribute to long-term carbon burial in the deep sea. Here we probe in detail the terrestrial versus marine origins of organic matter along a transect in Baltimore Canyon, as well as its bioavailability for benthic fauna, in order to explore how canyon-specific sediment dynamics might emplace a functional sorting of organic matter from shelf to open ocean. We present a novel approach to separate functional classes of organic matter and investigate sources and degradative pathways of organic matter in Baltimore Canyon. In combination with bulk geochemical characteristics, surface sediments from water depths of ~200 1200 m were sequentially extracted to separate nonpolar and polar lipid classes, an acid-hydrolysable fraction, and a non-hydrolysable fraction. Each class was analyzed for carbon and nitrogen quantities, stable isotope ratios, and radiocarbon content where possible, along with isotopic indicators derived from individual amino acids in the hydrolysed fraction. Our results highlight differences in provenance and bioavailability of organic matter along the canyon, which correlate to grain size and erosion/deposition dynamics. In addition, we suggest that a relatively simple determination of the concentration of hydrolysable organic matter may provide better information about the nutritional quality of sediments for benthic fauna compared to bulk carbon or nitrogen concentrations.

Assessment of the morphological impact on fishing grounds along canyon flanks using AUV high-resolution side scan sonar and bathymetry

Durán, R.[1], **Cabrera, C.**[1], Puig, P.[1], Amblas, D.[2], Sanchez-Vidal, A.[2], Freitas, L.[2], Boone W.[3], Langedock, K.[3], Fourie, F.[3]

[1] Institut de Ciències del Mar, Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain
[2] Departament de Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, Barcelona, Spain
[3] Marine Robotics Centre. Flanders Marine Institute (VLIZ), Belgium

Bottom trawling fishing is considered the most important direct anthropogenic stressor in marine environments, being an order of magnitude greater than all other anthropogenic activities in the deep sea. In the north-western Mediterranean, the fishing technique practised is otter trawling, which has a significant impact on seafloor morphology. The degree of environmental disturbance caused by bottom trawling on the seabed depends largely on the design weight of the otter board and the type of sediment.

In this work, we provide the first observations of fine-scale bathymetries on fishing grounds along Blanes and Palamós Canyon flanks. The fishing grounds were mapped in March 2023, using the AUV Barabas of Flanders Marine Institute (VLIZ), equipped with a Klein UUV-3500 high-resolution side scan sonar with interferometric bathymetry. Results revealed significant differences among the explored areas. In the Blanes Canyon, side scan sonar data show long, strongly marked furrow marks from trawl doors, corresponding to fresh trawl marks. The trawl marks have a penetration into the sediment of a few centimeters but it can be up to more than 1 meter when they concentrate forming deep trenches.

Flattened areas from ground ropes and nets with no characteristic topographical surface features are observed between groups of trawl marks. Additionally, local accumulations of sediment displaced and piled up by the action of bottom trawling appear at the end of the trawl trenches. In the Palamós Canyon, where the trawling fleet uses pelagic otter boards without contact with the seafloor since year 2017, deep trawl trenches were absent and most of the trawl marks appear smooth, suggesting that they are old. Nonetheless, the sonar imagery shows regular elongated, dashed marks, oblique to the direction of the fishing ground, that could be attributed to the impacts of the bridle chains with the seabed. The different morphological signatures in the fishing grounds of the Blanes and Palamós canyons suggests that the recent change of the otter boards from demersal to pelagic models in the Palamós trawling fleet has greatly reduced the physical impact of this anthropogenic activity on the canyon flank seafloor, preserving the integrity of the fishing ground.

Quantifying lateral fluxes of matter down submarine canyons to the deep sea with a simplified process model for turbidity currents

Joris T. Eggenhuisen[1]

[1] Faculty of Geosciences, Utrecht University, the Netherlands.

Submarine canyons are conduits for transport of matter from shallow to deep parts of marine basins and oceans. Turbidity currents have previously been modelled extensively to evaluate their role in down-canyon transport of sediment. But they are also involved in (re-)distributing a wide variety of other phases such as Particulate Organic Carbon (POC), nutrients, litter, micro- and nano-plastics, Peristant Organic Pollutants (POPs) or metal compounds adhered to clay particles, pharmaceutical compounds, salt, dissolved matter, and heat. The observational evidence from sea-going research on this broad range of themes is maturing, but process modelling approaches seem relatively underdeveloped for anything but modelling of sediment transport. New process-modelling approaches for fluxes down submarine canyons could make a complimentary contribution to sea-going research by extrapolating from measurements, interpolating between sparse data points, and reconstructing past and predicting future fluxes. This presentation will demonstrate the application of a simplified-process model for turbidity currents that can go some way to fulfilling this potential.

Modelling the flux of sediment during turbidity currents has been a challenge to sedimentologists due to the interdependence of the primary variables: The amount of sediment that can be transported depends on current strength, and the current strength is determined by the mass of sediment in transport. This challenge has mostly been overcome through synthesis of the combined work of the Eurotank Studies of Experimental Deepwater Sedimentology (EuroSEDS) and literature. The resulting Sediment Budget Estimator (SBE) models fluxes of sediment through submarine canyons at time scales from seconds to hundreds of thousands of years.

This presentation addresses (and calls for feedback on) the potential of the SBE to make a contribution to a broader range of marine-science research in submarine canyons, beyond the flux of sediment. I will present case studies of the model for transport down Monterey Canyon, model terrestrial POC flux down Congo Canyon, and illustrate complexities of modelling microplastic fluxes in turbidity currents.

Bringing new life to legacy imagery data: Developing methodologies to enhance geospatial use of legacy Deep Towed Imaging System (DTIS) imagery

Frontin-Rollet G.E.[1], Mountjoy J.M.[1], Davidson S.[1], Quinn W.[1], Eton, N.[1], Steinmetz T.[1], George S.[2]

[1] National Institute of Water and Atmospheric Research - Taihoro Nukurangi, Te Whanganui-a-Tara - Wellington, Aotearoa New Zealand
[2] National Institute of Water and Atmospheric Research - Taihoro Nukurangi, Christchurch, Aotearoa New Zealand

Developments in seafloor imagery technology have exponentially increased, enabling high accuracy (cm scale) modelling and analysis of modern seafloor environments. Although these techniques are being applied and tested with new, high-resolution imagery datasets, decades of legacy video and photo imagery and associated metadata exist in many institutions data archives. When combined with statistical modelling of metadata and ever-improving high-resolution bathymetric elevation datasets, legacy imagery can be as valuable, limited only by survey metadata and imagery quality. Therefore, the visualisation of these legacy data in a geospatially defined context presents a significant opportunity to further understand seafloor biodiversity, particularly with respect to how sensitive marine environments may change through time.

Here we present an example methodology that has enabled the geospatial visualisation of legacy DTIS (Deep Towed Imaging System) data collected across the Kaikōura Canyon in 2017. Further developments in the integration of legacy towed camera footage into popular geospatial software such as ESRI ArcGIS Pro offers support to further applications such as machine learning and in-depth geospatial analysis.

Upper Kaikōura Canyon: Shaken by de-fault

Laura Gnesko[1], Tim Stahl[1], Joshu Mountjoy[2], Jon Carey[3]

[1] University of Canterbury, New Zealand
[2] National Institute of Water and Atmospheric Research - Taihoro Nukurangi, Te Whanganui-a-Tara - Wellington, Aotearoa New Zealand
[3] University of Birmingham, United Kingdom

Submarine canyons are critical in source-to-sink routing of sediment to deep ocean basins. In November 2016, the Mw 7.8 Kaikoura earthquake ruptured multiple faults across the coast and into the Kaikoura Canyon, triggering a large number of submarine landslides and initiating an 850-megaton sediment flow that travelled > 680 km along the ocean floor. This study characterises extreme landscape change from a single event in the upper Kaikoura Canyon by combining (i) 1:1000 geomorphic mapping on pre- and post-event high resolution (0.5-2 m) bathymetry and (ii) quantitative analysis of bathymetric change to better understand the styles of failure during seismic events. Preliminary findings indicate widespread shallow failures in post-glacial sediment overlying bedrock with highly variable headwall retreat. Deep-seated failures are confined within the Kaikoura canyon and Haumuri canyon heads. The predominance of evacuated scarps within the canyon headwall, well developed gullies and lack of deposits suggests debris flow type failures that contributed to the turbidity current downslope. Thin, arrested translational slab failures were also mapped along the headwall. The average measured headwall retreat is ~15 m over 8.5 km distance with the greatest amount of retreat and volumetric loss observed in the Haumuri Canyon (average retreat of 25 m and up to 210 m), followed by the Kaikoura Canyon Head (average retreat of 20 m, up to 100 m). The results demonstrate that mechanisms and magnitudes of canyon failure are controlled by pre-event geomorphology, the geotechnical properties of soft sediment under dynamic loads, as well as site specific shaking intensity and geology. The observed failures differ from pre-event expectations, and highlight that detailed geomorphological mapping widens our understanding of recurrent submarine failures, headwall retreat, and local tsunami hazard.

New AUV bathymetric data unveils the shaping potential of dense shelf water cascades on the seafloor of Cap de Creus Canyon

Freitas, L.[1], Amblas, D.[1], Sanchez-Vidal, A.[1], Lastras, G.[1], Arjona-Camas, M.[1,4], Fos, H.[1], Puig, P.[2], Durán, R.[2], Cabrera, C.[2], Boone, W.[3], Langedock, K.[3], Fourie, F.[3]

[1] GRC Geociències Marines, Universitat de Barcelona, UB, Barcelona, Catalonia, Spain
[2] Institut de Ciències del Mar, Consejo Superior de Investigaciones Científicas ICM-CSIC, Barcelona, Spain
[3] Marine Robotics Centre, Flanders Marine Institute, VLIZ, Oostende, Belgium
[4] CEFREM-CNRS, Université de Perpignan Via Domitia, Perpignan, France

Oceanographic processes interact with submarine canyons promoting the erosion, transport and deposition of sediments. Although high-energy natural events such as landslides, storms or river floods have been considered the main triggers for the transport of sediments from the continental shelf to the deep sea through submarine canyons, recent research also highlights the influence of dense shelf waters (DSW) in facilitating this transfer process. Previous studies have demonstrated how the interaction of DSW with the seafloor can lead to significant erosion and induce large-scale morphological changes. In this context, this study focuses on the Cap de Creus Canyon, located in the northwest of the Mediterranean Sea, in the Gulf of Lion, seeking to describe in high-detail the geomorphological aspects of the canyon and the impact of the DSW on its shape. The study area was mapped in March 2023 using the AUV Barabas of the Flanders Marine Institute (VLIZ), equipped with a Klein UUV-3500 high-resolution side scan sonar with interferometric bathymetry, as part of the FAR-DWO project. It was observed that the upper canyon exhibits a flat-bottomed thalweg incised in a large sedimentary furrow. The linear furrow extends for kilometers into the canyon mid-course, reaching depths of up to 1,400 meters. On both sides of the canyon, the furrows are oblique and have different excavation levels. Mid-channel sediment bars are present locally in the thalweg. To support the analysis, high-resolution photographs were also collected alongside the furrow fields. In addition, a comparison of the AUV data with the MAK-1M side-scan sonar data obtained in August 2004 is proposed in order to identify possible morphological changes. The results of this detailed geomorphological study are expected to provide new insights into the influence of DSW overflows on submarine canyons morphodynamics.

Near-Bed Structure of Sediment Gravity Flows Measured by Motion-Sensing Boulder-Like "Benthic Event Detectors" in Monterey Canyon

Gwiazda[1] **R.**, Paull[1] C. K., Kieft[1] B., Klimov[1] D., Lundsten[1] E., McCann[1] M., Cartigny[2] M., Talling[2] P.

[1] Monterey Bay Aquarium Research Institute -MBARI, USA
[2] Durham University, UK

The near-bed section of submarine gravity flows is believed to consist of a fast, dense, and destructive layer. The presence of this layer makes it difficult to directly measure the flow properties within this critical region. To overcome this challenge, 'boulder-like' benthic event detectors (BEDs) that measure their own rotation, depth and temperature, while being carried within the near-bed region of the flow, were developed. BEDs were deployed in Monterey Canyon from 200 m to 500 m water depth over a distance of 50 km for 18 months during the Coordinated Canyon Experiment. Most BEDs were spherical, two were cubic and one was mounted along with an autonomous monitoring transponder (AMT) atop a >2 m tall, ~800 Kg tripod of >6 gr/cc density. Data recovered from the BEDs, as well as independent measurements made from moorings, show BEDs moved in 10 out of 14 gravity flows that transited the upper canyon. BEDs moved within the body of the flow because the initial velocities of the BEDs were 66 ± 16% (1 SD) of the flow transit velocities. BEDs rotated freely during most of their first moves and gained depth faster than in later moves, when their motion was more random and wobblier. In addition, after their first move, the variability in the environmental temperature signal they recorded between flows was reduced by ~50%. The differences in BED motions between first and later moves suggest BEDs moved at different depths within the flow and were buried after their first move. The inferred near-bed flow structure is strongly stratified with a fast, less-dense layer moving above a slower and denser layer. Coherent changes between pressure and acceleration indicate that BEDs rode a crescent shaped bedform (CSB) morphology that persisted throughout flow events. The variability in BED speeds while riding the CSB morphology indicates a fluid-like nature of the near-bed layer. Based on recorded temperature decay rates after flow events, the thickness of remobilized sediment is 2 to 3 m. Videos critical for conceptualizing the movements of the BEDs as they moved over the CSBs will be shown.

Faunal-mediated ecosystem functioning in a benthic deep-sea canyon community recovering from a severe seabed disturbance

Rachel Hale[1], Katharine T. Bigham[2,3], Ashley A. Rowden[2,3], Grace Frontin-Rollet[2], Jane Halliday[2], Scott D. Nodder[2], Alan R. Orpin[2], Katherine L. Maier[2], Joshu J. Mountjoy[2], Matthew Pinkerton[2]

[1] National Institute of Water & Atmospheric Research, Nelson, 217 Akersten Street, Port Nelson, Nelson, 7010, New Zealand
[2] National Institute of Water & Atmospheric Research, Wellington, 301 Evans Bay Parade, Hataitai, Wellington, 6021, New Zealand
[3] Victoria University of Wellington, Kelburn, Wellington 6012, New Zealand

Kaikōura Submarine Canyon is a deep-sea benthic biology hotspot with globally high faunal abundances. The 2016 Mw7.8 Kaikōura Earthquake triggered a canyon flushing event that evacuated an estimated 850 metric megatonnes of material down canyon, removing both seafloor substrate and associated organisms. Canyon habitats are now recovering from this large disturbance.

Here we relate post-event benthic macrofauna abundance and biomass to sediment community oxygen consumption (SCOC) and associated benthic macronutrient biogeochemical fluxes at ten sites along a depth transect down the Conway Trough and the main canyon axis. Infaunal bioturbation activities at three co-located sites down the main canyon axis are also presented.

We find distinct differences down-canyon in sediment organic matter composition and inputs, macrofaunal community structure, SCOC, and bioturbation behaviour.

The relationship between canyon depth and the measured ecosystem function processes is not linear, with SCOC and nutrient fluxes from the sediment (NH4-N, NOx-N, DRP) increasing with depth while infaunal biomass decreases. We find SCOC is linked to bioturbation behaviour and sediment organic matter content, rather than faunal abundance or biomass. We speculate that this finding is likely a consequence of the canyon flushing-event.

These observations provide a benchmark for future measurements of faunal mediated deep-sea canyon processes and the recovery trajectory of deep-sea benthic communities after large seafloor disturbances.

Faunal-mediated ecosystem functioning in a benthic deep-sea canyon community recovering from a severe seabed disturbance

Abbie Henneker, Marta Ribó, Helen Williams

Auckland University of Technology, AUT, New Zealand

Submarine canyons are deep-sea incisions into the continental margin, creating long undersea valleys with steep sides. They extend into the continental shelf and act as the prime conduit of sediment transport from land to the ocean. While sediment-filled canyons are well documented, the mechanisms of submarine canyon incision into bedrock are still poorly understood. Here we present a project that aims to understand the mechanisms of how coarse gravel sediment incises into and erodes bedrock. Our study is focused on the Kaikōura submarine canyon, located only 800m off the coast of Kaikōura, in the South Island of Aotearoa/New Zealand. This region experienced a magnitude 7.8 earthquake in November 2016. Subsequently, large amounts of sediment, including large blocks and boulders, were transported down-canyon, eroding the seafloor of the upper parts of the canyon.

In this study we analysed high-detail bathymetric data collected in 2020 along the Kaikōura canyon using an Autonomous Underwater Vehicle (AUV). We compare these observations with the outcrops of ancient submarine canyon deposits from the Miocene, which were used as analogues for the present-day processes occurring within the Kaikōura canyon.
Our investigations on how the bedrock of ancient submarine canyons has been eroded by large blocks and boulders are critical to help understand the key processes of bedrock submarine canyon incision.

Cold-water coral habitat responses to natural and anthropogenic disturbance: initial results from repeat observations in the Whittard Canyon system

Veerle A.I. Huvenne[1], Brian J. Bett[1], Tim P. Le Bas[1], Tabitha R.R. Pearman[1], David M. Price[2], James A. Strong[1], Josh Tate[3], Loic Van Audenhaege[1], Catherine Wardell[1]

[1] Ocean BioGeosciences, National Oceanography Centre, Southampton, United Kingdom

[2] IMAR-Instituto do Mar, Universidade dos Açores, Horta, Faial, Portugal

[3] Joint Nature Conservation Committee, Peterborough, UK

Submarine canyons are known to often host a high biodiversity, including Vulnerable Marine cosystems (VMEs) and other habitats of conservation interest (Cold-water coral reef; Coral garden-Hard bottom; Coral garden-Soft bottom; Deep-sea sponge aggregations; Seapen fields; Tube-dwelling anemone aggregations; Xenophyophore aggregations). Many submarine canyons are also rich fishing grounds, and severe impacts on VMEs, habitats and species have been reported. However, natural episodic processes, such as turbidity currents and canyon wall collapses equally impact submarine canyon habitats. So far, understanding of canyon habitat and community responses to these natural and/or anthropogenic types of disturbance is limited. Observations of recovery trajectories, and their timeline, are rare but extremely valuable for conservation planning and potential habitat restoration programmes.

In summer 2022, the RRS James Cook revisited the Whittard Canyon system on the Celtic Margin, NE Atlantic, which includes The Canyons Marine Conservation Zone. The aim of the expedition was to investigate the occurrence of, and potential changes in, small-scale habitat distributions and benthic community compositions compared to observations from 2009 and 2015. Cold-water coral habitats formed the main focus, particularly those on vertical walls. As developed in 2015, a nested approach was used, combining AUV-based mapping with ROV-based video surveys, photogrammetry and vertical mapping, and a 45-day DeepGlider deployment.

Here we present our preliminary results, providing evidence of coral growth and expansion on some vertical walls. However, no signs of recolonisation on previously trawled areas were found, probably because trawling was only banned on the canyon interfluves 2 months before the survey. Future surveys, potentially using fully autonomous systems, will be needed to confirm the initial trends observed so far.

Submarine microplastic segregation: bypass and storage in the Whittard Canyon, NE Atlantic

Ed Keavney[1], Ian A. Kane[2], Mike A. Clare[3], Peng Chen[2], David M. Hodgson[1], Veerle A. I. Huvenne[3], Esther J. Sumner[4], Furu Mienis[5], Jeff Peakall[1]

[1] School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK

[2] Department of Earth and Environmental Sciences, University of Manchester, Manchester, M13 9QQ, UK

[3] National Oceanography Centre, University of Southampton, Southampton, SO14 3ZH, UK

[4] School of Ocean and Earth Science, University of Southampton, SO14 3ZH, UK

[5] Department of Ocean Systems, Royal Netherlands Institute for Sea Research (NIOZ-Texel), Den Burg, The Netherlands

The deep ocean floor is the ultimate depositional sink for microplastic particles, yet an understanding of the processes and rates that govern their transfer, deposition, and burial remains largely unresolved. Here, we show that microplastic particles stored at a submarine canyon head are remobilized and transported to the deep sea via sediment gravity flows. Sediment samples from a sediment trap suspended 30 m above the canyon floor, and push cores (n=10) from two across-canyon transects have been collected from the Whittard Canyon, NE Atlantic. We determine the role of sediment gravity flows in deep sea microplastic transport along a submarine canyon using particulate grain size and shape analysis, and ADCP velocity measurements. Despite being a land-detached submarine canyon with no direct link to terrestrial microplastic inputs, the Whittard Canyon experiences turbidity current activity analogous to land-attached submarine canyons, with maritime activity thought to be the major source of microplastic pollution. Samples from the sediment trap (10 km from the canyon head), document, for the first time, microplastics being transported via turbidity currents (74 microfibres per 50 g dry sediment). At the up-dip transect (30 km from the canyon head), microplastic concentrations in the thalweg are low, and increase down-canyon (60 km from the canyon head) (from 8 to 15 microfibres per 50 g) where the flows become less confined. This is interpreted to indicate efficient bypass up-dip in the thalweg and the formation of depositional hotspots downdip. Within the downdip zone of increased sedimentation, high levels of organic matter are documented. At both transects, with increasing distance away from, and height above, the thalweg, microplastic concentration increases (18 microfibres per 50 g). This suggests that microplastics are a higher proportion of the particulate load in the upper, more dilute parts of turbidity currents. Our results demonstrate that turbidity currents transfer microplastics to the deep sea, and that submarine canyon morphology strongly controls the sites of microplastic bypass and storage. Better understanding of these transfer processes will aid in quantification of microplastic fluxes to the deep sea and forecasting microplastic hotspots, and their links to biological activity.

Controls on Carbon storage in near-surface sediments from the Whittard Canyon, N.E. Atlantic

Catherine Kershaw[1], Jonathan Dick[1], Martin White[2], Veerle A.I. Huvenne[3], Konstadinos Kiriakoulakis[1]

[1] Geography and Environmental Sciences, School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool, UK.

[2] Natural Sciences, College of Science and Engineering, University of Galway, Ireland

[3] Seafloor Ecosystems, Ocean Biogeosciences, National Oceanography Centre, Southampton, UK

The Whittard submarine canyon, (Celtic Sea, N.E. Atlantic), is a vast (100km in width, 150-4500m depth range), multi-branched feature of the N.W. European Margin, located 200km from the nearest coastline, hence well positioned to study how marine processes may shape it. The canyon system experiences complex hydrodynamics and shelters diverse benthic ecosystems. Recent work has shown that canyons can be hotspots of carbon sequestration, yet our comprehension of the controls is limited. This work endeavours to improve our insight into the canyon's role as a carbon sink, by evaluating the influence of its sedimentological characteristics and geomorphic attributes.
46 short (<30cm) cores from various depths and key locations within the canyon's branches were collected during three cruises (2013-15) and analysed. Grain size distributions exhibited multimodal tendencies, with sandy, silty, and clay components, including coarser materials at depths surpassing 1000m, indicating an interplay of diverse sedimentological and hydrodynamic processes. Organic carbon (OC) contents frequently exceeded the anticipated range for deep-sea sediments (>1.5% dry sediment weight), suggesting high, if variable, carbon storage potential within parts of the canyon system. Organic enrichment was evident in samples from the central channel at depths exceeding 3700m, potentially attributed to transport from upper canyon regions as well as vertical sinking. The Eastern branch displayed the lowest OC content, possibly reflecting an energetic sedimentary regime that promotes organic matter (OM) recycling.

$\delta^{13}C$ (‰ vs PDB) of bulk OM from selected surficial sediments were within typically marine ranges (~-24 to -22‰). A heavier value (-12.8‰) was detected at the connection of two central branches, tentatively indicating sulphide-oxidized carbon associated with the form II Rubisco pathway. Statistical analyses explored influences of morphology, sedimentology, branch location, depth, and potential anthropogenic activity in carbon storage, with grain size seemingly being a dominant control. The Eastern branch emerged as the most heterogeneous, possibly reflecting its energetic regime, elevated biodiversity and faunal abundance. The study's significance rests on the use of an extensive dataset of near-surface sediments, serving as a baseline resource, to evaluate the potential of the system as a carbon sink.

Exploring the evolution of submarine canyon-fan systems in active fault settings: Insights from physical experiments and morphodynamic modeling

Steven Y.J. Lai[1], **David Amblas**[2], Aaron Micallef[3], Thomas P. Gerber[4], Hérve Capart[5]

[1] Department of Hydraulic and Ocean Engineering, National Cheng Kung University, Tainan, Taiwan
[2] GRC Geociències Marines, Universitat de Barcelona, Barcelona, Catalonia, Spain
[3] Marine Geology and Seafloor Surveying, Dept. of Geosciences, University of Malta, Msida, Malta
[4] Equinor - Research and Technology, Austin, Texas, USA
[5] Department of Civil Engineering, National Taiwan University, Taipei, Taiwan

Variations in fault configurations contribute to the complex and diverse morphologies observed in submarine canyon-fan systems along active margins. In this research, we investigate the continuum of erosion, transportation, and sedimentation processes within fault-controlled canyon-fan systems using a combination of physical experiments and a morphodynamic model. Our investigation employs morphometric analyses to elucidate the presence of Hack's scaling relationships within submarine canyons and their associated fans. Additionally, we utilize Digital Elevation Models of Differences (DoDs) to unveil growth patterns and establish meaningful correlations between canyon volumes and the corresponding fan formations.

Our study uncovers compelling self-similarities in the longitudinal profiles of canyon-fan systems. Through a novel morphodynamic model, we capture their temporal evolution, including the dynamics of internal moving boundaries. Notably, we observe that the rate of fault slip significantly influences the rate at which coalescing submarine canyon-fan systems merge. Moreover, when we consider the interplay between fault slip rates and inflow discharge, a competitive influence emerges. Importantly, our investigation reveals scaling relationships that span from laboratory experiments to real-world field-scale scenarios. Our research presents valuable insights that can inspire and aid field researchers and modelers in their efforts to better comprehend and predict the morphological transformations and sedimentary processes occurring within submarine canyon-fan systems situated in active fault settings.

Trapped! Sunrise Topographic Blocking of Vertical Migrators at Steep Canyon Walls

Leitner, Astrid[1,2], Benoit-Bird, Kelly[2], Waluk, Chad[2], Sherlock, Rob[2], Reisenbichler, Kim[2], Robison, Bruce[2]

[1] Oregon State University, College of Earth Ocean and Atmospheric Sciencdes
[2] Monterey Bay Aquarium Research Institute

Submarine canyons are biological hotspots. Dynamic biogeophysical processes make these common coastal features ideal habitats for diverse benthic and pelagic communities. Monterey Submarine Canyon is a large, deep canyon whose dramatic bathymetry brings deep and shallow, pelagic and benthic communities into direct contact with each other. We investigated how diel vertical migration is impacted by canyon bathymetry, using bioacoustics, to determine whether topographic blocking of downward migrators is a regularly occurring phenomenon here. Between 2019 and 2023 an autonomous surface vehicle (WaveGlider) was equipped with a bioacoustics package to collect backscatter data over a large and steep canyon wall. Ten different surveys were run ranging from 3 to 17 days in duration, sampling all local oceanographic seasons. Sunrise aggregations were localized in the resulting data using an edge-detection algorithm. The biomass, dimensions, and locations in the water column relative to the bottom were subsequently characterized and quantified.

A benthic current meter was also deployed in conjunction with the bioacoustic surveys, while ROV video transects provided an understanding of community composition and fine-scale ecological dynamics around the canyon wall at sunrise. The resulting data demonstrate that topographic blocking is a common phenomenon that is influenced by both physical and ecological factors. Regular and predictable aggregations of prey, such as these topographically blocked migrators, have profound ecological consequences and may make these canyon walls sites of enhanced bentho-pelagic coupling and predator hotspots.

Bio-acoustic Characteristics in the Kao-Ping Submarine Canyon—Fish Chorus and marine mammal sounds

Linus Chiu[1], Barry B. Ma[2], Yiing-Jang Yang[3], and Wen-Hwa Her[3]

[1] Institute of Undersea Technology, National Sun Yat-sen University

[2] Applied Physics Laboratory and School of Oceanography, University of Washington

[3] Institution of Oceanography, National Taiwan University

The Kao-Ping Submarine Canyon (KPSC) stands as the largest canyon system in the southwestern waters of Taiwan. This study is dedicated to investigating the characteristics of the soundscape within the confines of the Kao-Ping Submarine Canyon. In the year 2023, a fully integrated mooring system was deployed within the expanse of the canyon, subsequently and successfully recovered, resulting in the collection of marine physics and acoustic data spanning a period of over a week. The main focus of this research revolves around exploring the bioacoustic attributes while concurrently examining the interaction between the biosoundscape and the physical oceanographic processes.

Within the field of bioacoustics, the extraction of biological sound signals leverages the capabilities of machine learning and artificial intelligence methodologies, primarily aimed at analyzing the collective vocalizations exhibited by specific fish populations and marine mammals. Moreover, this research conducts preliminary studies to uncover the connections between marine physical mechanisms and the subaqueous soundscape, intrinsically embedded within the canyon system. This endeavor receives support from the National Science Council of Taiwan.

Submarine canyon morphology along the Chilean marine forearc (19°S-45°S)

Shuang Li[1,2,3], Jacob Geersen[4], Sebastian Krastel[4], **Wei Li**[1,2,3]

[1] CAS Key Laboratory of Ocean and Marginal Sea Geology,
[2] South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, PR China
[3] University of Chinese Academy of Sciences, Beijing 100049, PR China
[4] Institute of Geosciences, Kiel University, Kiel 24118, Germany

Convergent margins host more than half of all global submarine canyons. In this environment, the lack of cognition of the canyon morphology variation and their controls in two different types of marine forearcs (erosive and accretionary) still exists. Based on shipborne bathymetric maps, we systematically analyze width, incision depth and slope gradient of 17 submarine canyons along the Chilean marine forearc. We divide the study area into an erosive northern area, a transitional central area, and an accretionary southern area based on trench sediment cover and in line with previous tectonic interpretations. In the northern and central areas, limited sediment supply and little erosion from infrequent turbidity currents form narrow and shallow canyons that arrive at the toe of margin. Subduction erosion contributes to a simple and regular slope morphology where regional subsidence and trench-parallel faulting activities lead to vertical crustal movement and a steep thalweg of canyons' lower reach. In contrast, frequent canyon flushing/filling turbidity currents and slope failures on the canyon walls result in a wider range of canyon width and incision depth in the south. Here, the formation of an accretionary prism generates fold and thrust ridges at the seafloor that reduce the slope gradient of canyons' lower reach. Canyon morphology within the prism region has a larger range than the non-prism (backstop) region due to the higher erodibility of the less consolidated sediment. In addition, convex-up step-shaped bedforms develop along 14 canyon thalwegs, also suggesting regional uplift/subsidence and normal faulting in the north and central region but folding and thrust faulting in the south. This work not only reveals the difference of canyon morphology on active marine forearcs but also may help to understand controls on submarine canyon morphologies along the Chilean margin as well as in other convergent margins.

The role of sediment gravity flows on the morphological development of a large land-detached submarine canyon (Taiwan Canyon), northeast South China Sea

Wei Li[1,2,3], Shuang Li[1,2,3], Tiago M. Alves[4], Michele Rebesco[5], Lingyun Wu[1,2,3], Zhongwei Zhao[1,2,3]

[1] CAS Key Laboratory of Ocean and Marginal Sea Geology, South China Sea Institute of Oceanology,

[2] Chinese Academy of Sciences, Guangzhou, 510301, China (E-mail: wli@scsio.ac.cn)

[3] University of Chinese Academy of Sciences, Beijing, 100049, China

[4] 3D Seismic Lab, School of Earth and Ocean Sciences, Cardiff University, Main Building, Park Place,Cardiff, CF10 3AT, UK

[5] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Borgo Grotta Gigante 42/C,Trieste, 34010, Italy

Submarine canyons are ubiquitous on the submerged continental margin and provide sediment, nutrients and pollutants from continental shelves to the deep sea. Land-detached submarine canyons are usually considered to have lower sediment transport capacity and lower activity. Here we investigate a large land-detached submarine canyon (Taiwan Canyon) on the northeast South China Sea margin with an extremely wide shelf (~200 km). This canyon has two main branches at its head, and changes its orientation from north-west/south-east to east-west due to the effect of a tectonically active seamount. Our results show that frequent storms (i.e., seasonal typhoons) play a significant role in the sediment disturbance along the continental shelf. The disturbed sediment can be further transported towards the lower slope, promoting the generation of turbidity currents and maintaining the activity of Taiwan Canyon. The asymmetry of Taiwan Canyon's banks in its middle reach is caused by the combined action of recurrent slope instability and turbidity currents. In addition, two fields of sediment waves were identified in the study area. Field 1 is located on the southwest levee of the canyon and is fed by turbidity currents from one of its branches, being also associated with marked hydraulic jumps. Field 2 is observed in the southern bank of the lower canyon reach and was formed by the overspill of turbidity currents within the Taiwan Canyon due to the effect of inertial centrifugal forces. Importantly, trains of plunge pools have been identified along the thalweg of the lower canyon reach, generated by turbidity currents deriving from the submarine canyons in the north of the Taiwan Canyon. Our results not only provide a detailed investigation of seafloor bedforms within and around a large land-detached submarine canyon, but also contribute to a better understanding of their origin and development. The high-resolution bathymetric and seismic data in this work reveal how gravity flows can drive erosion and deposition within submarine canyons.

Ecology and hydrodynamic drivers of black coral assemblages in Barkley Canyon, at the core of NE Pacific Oxygen Minimum Zone

Claudio Lo Iacono[1], Guillem Corbera[2], Paulo Ferraz Corrêa[4], Marta Arjona-Camas[2,3], Ruth Duran[1], Pere Puig[1], Fabio Cabrera De Leo[4,5]

[1] Institut de Ciències del Mar, Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain

[2] Departament de Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, Barcelona, Spain

[3] CEFREM-CNRS, Université de Perpignan Via Domitia, Perpignan, France

[4] Ocean Networks Canada, University of Victoria, BC, Canada

[5] Department of Biology, University of Victoria, BC, Canada

It is observed that low concentrations of dissolved oxygen (DO) act as natural stressors for deep-sea coral ecosystems. Nonetheless, recent findings are progressively challenging this notion. Here, we describe a surprisingly well-structured megabenthic community found at 780-1000 m deep cliffs in the severe hypoxic waters of Barkley Canyon (NE Pacific). This area is bathed by the NE Pacific Oxygen Minimum Zone (OMZ), spanning across a wide depth range (530-1450 m). Yet, ROV surveys revealed unexpectedly rich and well-preserved benthic assemblages, structurally dominated by the black coral Chrysopathes speciosa and the bubblegum coral Sibogagorgia cauliflora, together with other octocorals and sponges. These cliffs are also inhabited by hundreds of fish individuals mainly represented by Sebastolobus alascanus (shortspine thornyhead) including many juveniles, possibly indicating a nursery area. Preliminary results indicate that the abundance of structuring species decreases away from the canyon axis, suggesting that along-canyon hydrodynamic processes play a role in the maintenance of these ecosystems. Decade-long time-series from Ocean Networks Canada's NEPTUNE cabled seafloor observatory reveal extremely low average DO values (0.28 ml·L-1), with corresponding low average temperatures (3.6 °C). In-situ Acoustic Doppler Current Profiler measurements revealed the occurrence of semidiurnal internal tides with amplitudes of up to 200 m. We hypothesize that the breaking of internal tide waves on the steep topography of Barkley Coral Cliffs triggers the resuspension of sediments, which are rich in organic matter according to previous studies. Despite the permanent natural stressor of the OMZ's severe hypoxia, the well-developed black coral communities on the canyon cliffs may be thriving on an abundant and organic-rich suspended particle load provided by local hydrodynamics. Studies focusing on the ecological responses, physiological and metabolic adaptations of black corals to severe hypoxia are currently lacking. The present study will provide insights onto deep-sea ecosystem responses to long-term climate change, in particular in the E and NE Pacific, where OMZs are rapidly expanding due to climate change.

Sediment gravity flows independent of submarine channels erode regularly dispersed pockmarks offshore Big Sur, California

E. Lundsten[1], C. K. Paull[1], R. Gwiazda[1], S.C. Dobbs[2], D. W. Caress[1], L. A. Kuhnz[1†], M. Walton[3*], N.M. Nieminski[3+], M. McGann[4, T], Lorenson[3], G. Cochrane[3], J. Addison[4]

[1] Monterey Bay Aquarium Research Institute, Moss Landing, CA.

[2] Stanford University, Palo Alto, CA.

[3] U.S. Geological Survey, Santa Cruz, CA.

[4] U.S. Geological Survey, Menlo Park, CA. †Retired *Currently at U.S. Naval Research Laboratory, Bay Saint Louis, MI. + Currently at Alaska Division of Geological & Geophysical Surveys, Anchorage, Alaska.

Recent surface ship multibeam surveys of the Sur Pockmark field, offshore Central California, reveal >5,000 seafloor pockmarks in an area that is slated to host an offshore wind farm. The pockmark field, between 500 and 1,500 meters water depth (mwd), is bisected by two submarine channels. Some pockmarks occur in chains within one of the submarine channel systems, however, most of the pockmarks are regularly dispersed and well separated from the channels and levees. Extensive fieldwork was recently conducted to characterize the seafloor environment and its recent geologic history. These observations, aimed at capturing the morphology and stratigraphy of the pockmarks, included visual inspections with remotely operated vehicles, sediment coring, and high resolution, sub-bottom Chirp and multibeam mapping surveys with autonomous underwater vehicles. Pockmarks do not appear to be formed by gas flow as we found no evidence of high methane concentrations in sediments, chemosynthetic biological communities, or methane-derived diagenetic byproducts. Chirp data and sediment cores show alternating layers of slowly accumulating hemipelagic sediment, that are interrupted by coarser-grained, more reflective turbidite horizons extending throughout the pockmark field and beyond. Chirp data show multiple episodes of lateral pockmark migration over time in association with erosion and infilling events. Laterally continuous turbidite horizons that overlay erosional surfaces and radiometric dating indicate that pockmark erosion and lateral migration occurred synchronously within the pockmark field. These migrations are presumed to be the result of asymmetrical erosion of the flanks of the pockmarks caused by passing sediment gravity flows. We hypothesize that intermittent, unconfined sediment gravity flows occurring over the last 400,000 years are the source of the regionally continuous turbidites and the mechanism that maintains the regularly dispersed, long lasting pockmarks.

Internal tides regulate the sediment dynamic processes in the deep-sea bottom boundary layer

Danni, Lyu[1], Yanwei, Zhang[1], Zhifei, Liu[1], Yulong, Zhao[1], Weihan, Ruan[1]

[1] State Key Laboratory of Marine Geology, Tongji University, Shanghai, China

Understanding the sediment dynamics in the deep-sea bottom boundary layer (BBL) is basic for interpreting marine sedimentary records. Due to the lack of in-situ observations, the temporal variations of sediment suspension and transport in the deep-sea bottom boundary layer haven't been systematically studied. High-resolution observations of the BBL flow field at water depth of ~2100 m in the northeastern South China Sea have been conducted with an integrated tripod system. According to 7-month time series measurements, the vertical structure of BBL velocity exhibits intermittent top and bottom intensification, which is persistently regulated by internal tide critical reflection and nonlinear internal waves (NLIW). The bottom intensified velocity in the BBL is stronger in winter and weaker in spring and autumn. Internal tide caused 200 local sediment resuspension (LSR) events owing to enhanced bottom shear in the flood peak and ebb peak stages during the spring tide. The BBL velocity in these stages was 8-30 cm·s-1 and the bottom shear was 10 times stronger than the background value (~0.1 s-1) for 2-12 hours, resulting in an abrupt increase of the suspended sediment concentration (SSC) up to 7.8 mg·L-1. After resuspension, the sediment was consequently transported away along with the high tidal velocity, resulting in a rapid decrease of SSC together with the reduction of bottom shear. On the other hand, NLIWs resulted in 32 more intense LSR events, featured with higher velocity (35 cm·s-1) and SSC (22.4 mg·L-1), but the duration of high bottom shear they maintained was shorter (≤1h). Due to the low horizontal transfer, sediment resuspended by NLIWs tended to settle down locally and slowly, sustaining the high SSC up to 6h. The internal tide contributed the most to the deep-sea sediment transport, which was estimated up to ~160.72 Mt to the southwest, accounting for ~57.91% of the annual discharge of fluvial sediments (~278 Mt) in the northeastern South China Sea. The direct mooring observation confirms the velocity structure and sediment resuspension vary at internal tidal and interseasonal time scales, which is crucial to improve the traditional sedimentary dynamic theory in the deep-sea BBL.

Characterize Acoustic Environment in the Kao-Ping Submarine Canyon – can we the hear the hyperpycnal flows?

Barry B. Ma[1], Yiing-Jang Yang[2], Linus Chiu[3] and Wen-Hwa Her[2]

[1] Applied Physics Laboratory and School of Oceanography, University of Washington
[2] Institution of Oceanography, National Taiwan University
[3] Institute of Undersea Technology, National Sun Yat-sen University

The Kao-Ping Submarine Canyon (KPSC) is located in southwest Taiwan. The unique geography and location, with multiple noise sources, make it a unique place to study the acoustic environment. To statistically understand and describe the underwater environment in temporal, spatial, and spectral scales and investigate the changes in the sound environment in various significant events, such as high wind (typhoons) and hyperpycnal flows (sediment flows). We deployed a surface mooring with Acoustic Doppler Current Profilers, temperature sensors, CTD, passive acoustic array, and turbidity sensors at a depth of ~350 m. A shipboard survey was conducted to collect gravity core, hydrographic, and underway echo intensity data. The meteorology data was also collected from a nearby surface buoy. We will present synthesized results and findings of the acoustic environment in KPSC.

Mapping Spatial and Temporal Variability of Turbidity Within the Whittard Canyon System to Investigate Mechanisms of Sediment Resuspension and the Triggering of Turbidity Currents

Eilean MacDonald[1], Rob Hall[1], Dorothee Bakker[1], Mike Clare[2], Furu Mienis[3]

[1] Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia, Norwich Research Park, Norwich NR4 7TJ, UK

[2] National Oceanography Centre, University of Southampton Waterfront Campus, Southampton SO14 3ZH, UK.

[3] Royal Netherlands Institute for Sea Research, Department of Marine Chemistry and Geology, P.O. Box 59, 1790 AB Den Burg, The Netherlands

Whittard Canyon is a large dendritic land-detached submarine canyon system incising the SW Celtic continental shelf. It was previously thought that land-detached canyons were largely dormant in the context of shelf to deep sea transport of carbon, sediment and pollutants due to their distance from coastal processes. However, recent observations suggest that Whittard is significantly active, featuring turbidity currents of a similar frequency (6 yr-1) and speed (5-8 m s-1) to those in land-attached submarine canyons (Heijnen et al., 2022). The triggering mechanisms of these turbidity currents are currently unknown, but seasonal variability of cross-shelf sediment transport and internal waves have been identified as possibilities.

An archive of 103 CTD casts from 6 international research cruises between 2009-2022 was compiled. The cast sites were primarily distributed within the eastern branch of Whittard Canyon and Explorer Canyon. The archive contains both hydrographic variables (e.g. temperature, salinity, dissolved oxygen) and optical variables (e.g. chlorophyll fluorescence, beam attenuation – a proxy for turbidity). The spatial and temporal distribution of high turbidity events, potentially linked to turbidity currents, was visualised using maps of near-bed turbidity, along- and across-canyon sections and revisited site time series.

Results showed increased turbidity in the bottom 200 m of the casts 10-50 km from the canyon head along the eastern branch thalweg. Within Explorer Canyon increased turbidity was observed in the bottom 200 m above the canyon walls on each side of the thalweg. A multi-year time series of 8 casts within the eastern branch showed a maintained near-bed increased turbidity layer that varied in intensity and thickness (50-200 m).

These results suggest there are areas within both the eastern branch and Explorer Canyon that are more sedimentologically active, with hotspots both along the thalwegs and above the walls. Additionally, there are areas within the canyon system that have a baseline of increased turbidity that may be independent of irregular turbidity current events. Understanding the baseline of turbidity and its variability is required to further investigate the relationship between the geomorphological/ hydrographic environment and turbidity current occurrence/magnitude. This will impact the current understanding of carbon and sediment budgets in similar land-detached canyons globally.

Sediment and carbon transfer and sequestration in Kaikōura Canyon, offshore Aotearoa/ New Zealand

Katherine L. Maier[1], Scott D. Nodder[1], Stacy Deppeler[1], Oliver Twigge[1], Rachel Hale[2], Catherine E. Ginnane[3], Sebastian Naeher[3], Peter Gerring[1], Grace Frontin-Rollet[1], Jocelyn Turnbull[2], Robert G. Hilton[4]

[1] NIWA, Wellington, Aotearoa/New Zealand
[2] NIWA, Nelson, Aotearoa/New Zealand
[3] GNS Science, Aotearoa/New Zealand
[4] University of Oxford, United Kingdom

Submarine canyons are important environments for sediment and organic matter accumulation and transport into the deep sea. Despite a recent paradigm shift in measuring flows within canyons, sampling and analysing near-seafloor sediment transport and deposition across timescales remains challenging. The SW Pacific is a significant driver in global submarine canyon organic carbon compilations, but available data are rare. Recent efforts in the Kaikōura Canyon–Hikurangi Channel system, following a large canyon-flushing event triggered by the Mw 7.8 November 2016 Kaikōura earthquake, present an opportunity to pair measurements and analyses of short-term events, background processes, and seasonal variations from a shore-connected canyon. Experimental sites included deployment of a near-seafloor mooring with a sediment trap at ~15 m above the seafloor, a benthic lander with a sediment trap at ~2 m above the seafloor, and repeated multicores across the sediment-water interface.

Compared to other global submarine canyons, event frequency appears to be lower in Kaikōura Canyon and comprised of more marine-derived organic carbon. Sediment flux and organic carbon content and composition vary down-canyon and over time, on much shorter timescales than earthquake recurrence (~100-200 years). Small-scale sediment flux events measured within a three-week deployment at ~900 m water depth in Kaikōura Canyon show lower organic carbon and nitrogen content, with decreased (more terrestrial) $\delta 13C$ and $\delta 15N$ signatures, compared to intervening times, despite increased organic carbon and nitrogen fluxes during what appear to be turbidity currents. Organic carbon and mass fluxes increase closer to the seafloor and decrease down-canyon. Burial efficiency appears to be high in some parts of the canyon but may be short-term owing to biological activity in the sediment. The composition, provenance and age of organic carbon is traced through the canyon into the deeper end of the depositional system using RPO-AMS and Py-GC-MS analyses of the earthquake-triggered Kaikōura event bed deposit. These analyses revealed similarities and subtle partitioning along >1200 km run-out distance within the Hikurangi Channel depositional system. This study provides the first detailed assessment of organic carbon flux, content and composition in a submarine canyon system offshore Aotearoa/New Zealand and contributes towards national and global budget compilations.

After a Decade of Surveys, Can We Adequately Characterize Western North Atlantic Canyons and Determine Broad-Scale Patterns in Deep-Sea Coral Diversity in this Region?

M.S. Nizinski[1], M. Rhode[2], M. Poti[3], T. Shank[4], T. Heyl[4], D. Packer[2], E. Shea[5]

[1] NOAA/NMFS National Systematics Lab, Smithsonian Institution, Washington, DC, USA.
[2] NOAA/NEFSC/James J. Howard Marine Sciences Lab, Highlands, NJ, USA.
[3] NOAA/NOS, National Centers for Coastal Ocean Science, Silver Spring, MD, USA.
[4] Woods Hole Oceanographic Institution, Woods Hole, MA, USA.
[5] Delaware Museum of Nature and Science, Wilmington, DE, USA.

The western North Atlantic Ocean is often described as one of the best-known bodies of water worldwide. However, over the last decade, new technologies have allowed greater access to areas difficult to survey leading to new discoveries in the region. Although scientists and resource managers identified submarine canyons as a top research priority, it was only recently that a concentrated field effort was undertaken to explore canyons off the eastern United States. Over an eight-year period, we conducted eight missions to 30 canyons, primarily to document and survey deep-sea coral habitats. Using ship-based multibeam mapping systems, towed-camera, and remotely operated vehicles, we collected multibeam bathymetry, still imagery, high-definition video and physical samples in all canyons explored. Habitat suitability models for deep-sea corals were field-tested and ground-truthed. Using imagery collected, we assessed the local and regional species richness, distribution and abundance of deep-sea corals in relation to canyon, latitude, and depth. Surveys also revealed new discoveries including biodiversity hotspots, species new to science, novel natural history observations, as well as refined and augmented information on the bathymetric and geographic distributions for a variety of taxa. These summarized data were then analyzed to determine if broad-scale patterns were evident for corals relative to these attributes over an extensive geographic range. Species richness of corals did differ relative to canyon and with depth. However, differences in species richness relative to latitude were not as apparent. These results will provide the necessary information to strengthen conservation decisions and advance species distribution models for the region to help refine our approaches to conserving these resources and expanding their protection in the future.

Is organic carbon enriched in submarine canyons around Aotearoa/New Zealand?

Nodder, Scott D.[1], Maier, Katherine L.[1], Watson, Sally J.[1,2], Leduc, Daniel[1], Rowden, Ashley A.[1,3], Hale, Rachel[4], Swales, Andrew[5], Gibbs, Max[5], Mountjoy, Joshu J.[1], Orpin, Alan R.[1], Woelz, Susi[1], Frontin-Rollet, Grace[1,3], Davidson, Sam[1]

[1] National Institute of Water & Atmospheric Research (NIWA) Ltd/Taihoro Nukurangi, Te Whanganui-a- Tara/ Wellington, Aotearoa/New Zealand (NZ)

[2] University of Auckland/Waipapa Taumata Rau, Tãmaki Makarau/Auckland, Aotearoa/NZ

[3] Victoria University of Wellington/Te Herenga Waka, Te Whanganui-a-Tara/Wellington, Aotearoa/NZ

[4] NIWA, Whakatû/Nelson, Aotearoa/NZ

[5] NIWA, Kirikiriroa/Hamilton, Aotearoa/NZ

The seascape surrounding the uplifted landmass of Aotearoa/New Zealand (NZ) is complex and dynamic, reflecting the active tectonic plate boundary, high uplift and erosion rates and vigorous maritime climatic and oceanographic processes. The NZ continental margin is dissected by numerous geomorphologically diverse submarine canyon systems that span a range of geological settings and of which only a small proportion have been studied in detail. Globally, canyons are known as sites of organic matter enrichment with a multitude of oceanographic, geomorphological and biological factors affecting organic matter accumulation. To what extent this variation among canyons, and their environmental context, influences organic matter accumulation in canyons compared to the surrounding continental slope is unknown.

A recent compilation of offshore organic carbon and physical textural data provides an opportunity to investigate whether seabed organic carbon concentrations are enriched in NZ canyons compared to the surrounding continental slope. This study focuses on several submarine canyons off the west and east coasts Te-Ika-a-Mãu/North Island, including from the passive Taranaki continental margin, the volcanic-dominated Te Moana-a-Toi/Bay of Plenty and the active Hikurangi Subduction Margin. We also compare and contrast the west and east coast of Te Waipounamu/South Island, using Kaikōura, Hokitika, and Otago canyon systems . Organic carbon in NZ canyons ranges from <0.05 to ~2%, which overlaps with the organic carbon content in surficial sediments on adjacent continental slopes. The lability of the organic matter in submarine canyons, based on C:N molar ratios, is generally less than on continental slopes, broadly reflecting greater terrestrial influence in canyons. Hokitika Canyon shows a much wider range of %Organic Carbon and C:N ratios than the other canyons, being typically less enriched in organic carbon with more refractory organic matter (high C:N). Biomarkers and compound-specific isotopes show that terrestrial organic material is transported seaward over 200 km into deep-water within Hokitika Canyon, compared to ~25 km in Kaikōura Canyon where the marine contribution to organic carbon is dominant (70-80% of total organic carbon).

Direct and deferred trawling-induced sediment transport events downslope a fishing ground on the flank of Blanes Canyon

Palanques, A.[1], **Puig, P.**[1], Martín, J.[2], Durán, R.[1], Cabrera, C.[1], Paradis, S.[3]

[1] Institut de Ciències del Mar, Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain
[2] Departament de Dinàmica de la Terra i de l'Oceà, Universitat de Barcelona (UB), Barcelona, Spain
[3] Geological Institute, ETH Zürich, Zürich, Switzerland

The impact of bottom trawling resuspension in Blanes Canyon has been recently documented by changes of sedimentation rates and anomalous increases of downward particulate fluxes. To study the sediment transport mechanisms induced by trawling activities, a mooring array equipped with an Acoustic Doppler Current Profiler and five turbidimeters was installed at 1035 m depth below the Peneca fishing ground, on the western flank of Blanes Canyon (NW Mediterranean). Previous observations conducted in the neighbouring Palamós Canyon revealed daily downslope sediment gravity flows during fishing hours but not during weekends. However, in the Blanes Canyon, sediment gravity flows were less frequent and occurred also during weekends and non-fishing hours. The highest suspended sediment concentration (SSC) of the gravity flows recorded during fishing hours ranged between 40 and 110 mg L-1 at 5 meters above bottom (mab) and were not well correlated with the highest magnitude of the current speed increases that occurred simultaneously. These events generated resuspension plumes 50 to 70 m in thickness. In contrast, the highest SSC of the gravity flows recorded during non-fishing hours and weekends ranged from 35 to 600 mg L^{-1} at 5 mab and were correlated with the highest values of the simultaneous current speed increases. These other events produced plumes only 30 m thick.

A video transect was subsequently recorded with a Remotely operated Vehicle (ROV) across the canyon flank where the mooring was located. ROV images showed terrigenous and biogenic debris accumulated near the mooring site. Upslope, in a region where a network of gullies develops, mud clasts and traces from when they rolled downslope could be frequently observed in the footage. At the deepest limit of the fishing ground, the seafloor appeared severely disturbed with a high density of deep trawling tracks and loose ploughed sediment blocks. All these observations suggest that bottom trawling resuspension along canyon flanks can not only directly induce downslope sediment gravity flows. They can also pile up sediment at the edge of the fishing grounds that become unstable and collapses downslope sometime after, evolving into thinner and more concentrated sediment gravity flows.

Global distribution of organic carbon content and age in submarine canyons

Sarah Paradis[1], Aline Wildberger[1], Negar Haghipour[1], Pere Puig[2], Albert Palanques[2], Claudio Lo Iacono[2], Furu Mienis[3], Henko de Stigter[3], Francisco J. Lobo[4], Ángel Puga-Bernabéu[5], Adi Torfstein[6], Oded Katz[7], Aaron Micallef[8], Anna Sánchez-Vidal[9], Xavier Durrieu de Madron[10], Fabio De Leo[11], Scott Nodder[12], Antonio Pusceddu[13], Silvia Bianchelli[14], Tim Eglinton[1]

[1] Geological Institute, ETH Zürich, Zürich, Switzerland
[2] Institut de Ciències del Mar, Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain
[3] NIOZ Royal Netherlands Institute for Sea Research, Den Burg, the Netherlands
[4] Instituto Andaluz de Ciencias de la Tierra, Consejo Superior de Investigaciones Científicas (IACT-CSIC), Granada, Spain
[5] Departmento de Estratigrafía y Paleontología, University of Granada, Granada, Spain
[6] The Institute of Earth Sciences, Hebrew University of Jerusalem, Israel
[7] Geological Survey of Israel, Yeshayahu Leibowitz 32, Jerusalem 9692100, Israel
[8] Monterey Bay Aquarium Research Institute, California, USA
[9] Departament de Dinàmica de la Terra i de l'Oceà, Universitat de Barcelona (UB), Barcelona, Spain
[10] CNRS-Université de Perpignan Via Domitia, Centre de Formation et de Recherche sur les Environnements Méditerranéens (CEFREM), Perpignan, France
[11] Ocean Networks Canada, Victoria, British Columbia, Canada
[12] National Institute of Water and Atmospheric Research (NIWA) Ltd, Wellington, New Zealand
[13] Dipartimento di Scienze della Vita e dell'Ambiente, Università degli Studi di Cagliari, Cagliari, Italy
[14] Department of Life and Environmental Sciences, Polytechnic University of Marche, Ancona, Italy

Submarine canyons are ubiquitous geomorphological features of continental margins that serve as important pathways of organic carbon (OC) transfer from coastal environments to deep-sea basins. Through the FACTS project, we compiled surficial sedimentological (e.g., grain size, mineral surface area) and geochemical (e.g., OC, δ13C, Δ14C) data from 48 submarine canyons incising continental margins worldwide to understand the processes that modulate the variations in the quantity, origin, and age of OC.

Despite a general fining of surficial sediments with increasing depth, OC content generally decreased downcanyon in all submarine canyons. This trend is attributed to the degradation of OC with increasing transit time, as observed by the general decrease in OC loading. The downcanyon degradation of OC is further supported by the general decrease of Δ14C, indicating an overall ageing of OC with across-margin distance. However, certain submarine canyons (e.g. Calahonda and Mackenzie canyons) did not follow this trend, and instead, presented a general increase in Δ14C, due to the deposition of older (e.g., petrogenic) OC in the canyon head that became progressively diluted by fresh marine OC input offshore. These results reveal that the primary driver of the contrasting OC signatures accumulating in submarine canyons worldwide is the origin and age of the OC delivered into the continental margin, whereas post-depositional processes promote its downcanyon ageing.

To better understand the factors that affect the distribution of the origin of OC in submarine canyons, we analysed biomarkers (proteins, lipids and specific fatty acids, carbohydrates, as well as phytopigments) and compound-specific-isotope-analyses (CSIA) in fatty acids of three contrasting submarine canyons incising the Gulf of Palermo, Sicily. Although all canyons presented a decreasing contribution of terrestrially-derived biomarkers downcanyon, Oreto Canyon did not present the greatest terrestrial fraction despite its proximity to a river mouth. Instead, Eleuterio Canyon, located downcurrent within the Gulf, had the greatest terrestrial OM contribution. These results reveal that along-margin hydrodynamic processes also govern the dispersal of OM across these geomorphological features.

Selecting the best framework to model Antipatharia distributions in the Northeast Atlantic deep sea

Alexa Parimbelli[1], Mark P. Johnson[1], Kerry Howell[2], Claire Laguionie-Marchais[1,3], A. Louise Allcock[1]

[1] Ryan Institute & School of Natural Sciences, University of Galway, University Road, Galway H91 TK33, Ireland
[2] School of Biological and Marine Science, Plymouth University, Plymouth PL4 8AA, UK
[3] Present address: Muséum National d'Histoire Naturelle, 57 rue Cuvier, 75005 Paris, France

Black corals are slow-growing, long lived organisms classified as Vulnerable Marine Ecosystem (VME) indicators, as they are able to create habitats (gardens) inhabited and used as a spawning ground by a wide range of organisms. Species distribution modelling has proven to be an effective tool to locate the presence of these coral hotspots in the deep-sea.

We used occurrence data gathered from HD video footage collected on canyons and sea mounds and an array of twelve environmental variables to model the predicted distribution of nine black coral morphotypes in the deep northeast Atlantic. In an attempt to identify a preferred method to model the distribution of cold-water coral species, the models were built using four different frameworks (MaxEnt with no variable pre-selection, MaxEnt with pre-selected variables, GBM with no-variable selection, and GBM with pre-selected variables); an overfitting analysis was then conducted to evaluate the model capability of predicting in new locations.

Despite models built with GBM obtaining higher scores in terms of model performance, they showed a higher degree of overfitting than their MaxEnt counterparts. Similarly, variable pre-selection prior to modelling negatively influenced the model performance, but decreased model overfitting. Moreover, in some cases models built with different frameworks produced similar predictive maps for the same morphospecies. In other cases, maps obtained from different modelling framework showed a substantial difference in the distribution of the same morphospecies, suggesting that the choice of modelling algorithm could lead to different predictions of VME site occurrence.

Assessing the cummulative impact of sediment gravity flows within Monterey Canyon over the last quarter century

Charlie Paull[1], Eve Lundsten[1], Dave Caress[1], Roberto Gwiazda[1], Monica Schwehr[2], Nora Nieminski3, Jim Barry1, Jingping Xu4, Mary McGann[5], Tom Lorenson[6], Katie Maier[7], and Pete Talling[8]

[1] Monterey Bay Aquarium Research Institue, Moss Landing, California, USA
[2] University of New Hampshire, Durham, New Hampshire, USA
[3] Alaska Geological and Geophysical Surveys, Anchorage Alaska, USA
[4] Southern University of Science and Technology, Shenzhen, China
[5] United States Geological Survey, Menlo Park, California, USA
[6] United States Geological Survery, Santa Cruz, California, USA
[7] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[8] Durham University, UK

Extensive work over the last 25 years within Monterey Canyon, offshore central California, provides an overview of the depositional patterns through the >150 km long channel extending from the head of Monterey Canyon to its fan in >3900 m water depths (mwd). Flow monitoring, repeat mapping, and sediment coring show that sand in the submarine canyon system primarily moves by discrete sediment gravity flows which vary in size, frequency, and runout distance. Collectively, these data reveal the movement of sand along the canyon floor and for how long it is staged on its way before ultimately reaching the submarine fan. Sediment gravity flows occur at a sub-annual frequency in the upper reaches (<1500 mwd) of the canyon, and show significant sediment transport capability as they cause ±3 m changes in the upper canyon floor and have displaced entire moorings down canyon. However, net sediment accumulations have not been documented above 1500 mwd, suggesting the upper canyon is primarily a pass-through conduit. Net deposition has been detected between 1500–1850 mwd, where the axial channel widens in the form of giant bedforms. Geochronologic data of sediment samples taken from core transects collected in the lower canyon show no evidence that sand-carrying sediment gravity flows have passed below 2870 mwd in the last quarter century. The most recent flow that deposited sand throughout the channel extending between the lower channel at 2870 mwd to 4000 mwd occurred approximately a century ago, suggesting recurrence at centennial frequencies. Sand-rich turbidites on the surface of the Monterey fan indicate that flows escape the confined submarine fan channel on millennial timescales. The imbalance between the sub-annual sediment transport in the upper canyon and the lack of sediment deposition below 2870 mwd over the last century implies that the mid-canyon (1300–2300 mwd) is serving as a temporary sand storage reservoir. Presumably, the sand accumulating within this reservoir ultimately gets dispersed across the submarine fan by larger sediment gravity flows on millennial timescales.

Recent sedimentary processes along submarine canyons of southern Italy: insight from morphobathymetric data and ROV observations

Martina Pierdomenico[1], Daniele Casalbore[2], Domenico Ridente[3], Denise Petronelli[2], Francesco Latino Chiocci[2]

[1] Institute for the Study of Anthropic Impact and Sustainability in the Marine Environment, National Research Council (IAS-CNR), Italy
[2] Department of Earth Sciences, "Sapienza" University of Rome, Italy
[3] Institute of Environmental Geology and Geo-Engineering, National Research Council (IGAG-CNR), Italy

Shelf-indenting submarine canyons having their headwall close to the coastline, such as those occurring along the tectonically-active continental margin of Calabria (southern Italy), act as main conduits for sediments transported by stream outflows and/or littoral drift, from coastal toward bathyal areas.

A dataset including high-resolution bathymetry and Remotely Operated Vehicle (ROV) videos was collected along the Gioia-Petrace and Punta Alice canyons (in the Tyrrhenian and Ionian side of Calabria region respectively), which deeply indent the continental shelf up to very shallow depths of 8-10 meters at reduced distances from coastline.

The analysis of morphobathymetric data revealed a variety of erosive-depositional features indicating active sediment transport. These include landslide scars and gullies on flanks, as well as migrating upper flow regime bedforms and knickpoints along the thalweg, observed in all canyons and mostly related to the action of recent instability processes and sedimentary gravity flows. The aim of this work is to integrate morphobathymetric data with ROV observations, acquired between 10 and 480 m depth, in order to determine small-scale morphological and sedimentological seafloor characteristics associated with the above-mentioned sedimentary features and to compare them among the different canyons. Evidence of erosion was observed on videos along the crests of the bedforms and the canyons' flanks, together with the occurrence of squared mudstone blocks with a fresh appearance at the base of the knickpoints, thus suggesting a very recent sedimentary activity of the studied canyons in their upper reach. A strong role of riverine and coastal inputs as sediment sources is testified by the abundant terrestrial or coastal vegetal material and land-sourced litter occurring along the thalweg and often embedded within the seafloor. The differences observed among canyons could be attributed to their different physiographic and oceanographic settings, which can influence the sedimentary inputs and prevalent transport mechanisms along canyons.

A geoscience perspective on transport mechanisms and global accumulation of litter in submarine canyons

Martina Pierdomenico[1], Anne Bernhardt[2], Joris T. Eggenhuisen[3], Michael A. Clare[4], Claudio Lo Iacono[5], Daniele Casalbore[6], Jaime S. Davies[7,8], Ian Kane[9], Veerle A.I. Huvenne[4] and Peter T. Harris[10]

[1] Istituto per lo studio degli Impatti Antropici e Sostenibilità in ambiente marino, Consiglio Nazionale delle Ricerche (IAS-CNR), Rome, Italy
[2] Institute of Geological Sciences, Freie Universität Berlin
Berlin, Germany
[3] Faculty of Geosciences, Utrecht University, Utrecht, Netherlands
[4] Ocean BioGeoscience, National Oceanography Centre, Southampton, United Kingdom
[5] Institut de Ciències del Mar, Spanish National Research Council (CSIC), Barcelona, Spain
[6] Dipartimento di Scienze della Terra, Sapienza Università di Roma, Rome, Italy
[7] School of Marine Science and Engineering, University of Plymouth, Plymouth, United Kingdom
[8] School of Marine and Environmental Science, University of Gibraltar, Gibraltar, Gibraltar
[9] School of Earth and Environmental Sciences, University of Manchester, Manchester, United Kingdom
[10] GRID-Arendal, Arendal, Norway

Marine litter and microplastics have reached every area of the Global Ocean, including remote settings such as the deep seafloor, where the magnitude and impacts of the problem is still largely unknown. Submarine canyons, acting as preferential conduits connecting shallow to abyssal depths, are widely recognized as main vectors for litter transport and accumulation in the deep sea, but several knowledge gaps exist about the pathways and processes that control the inputs, distribution and ultimate fate of anthropogenic debris within canyons. In this work, we provide a global perspective on the role of submarine canyons in transporting and accumulating litter, taking a geological, process-based point of view. Specifically, we evaluate different terrestrial and maritime sources and transport mechanisms of litter within canyons to assess the main natural and anthropogenic factors responsible for its accumulation in the deep sea. We then estimate the potential exposure of individual canyons to riverine and fishing-related litter on a global scale. Canyons represent focal points for accumulation of both land based and maritime-based litter, the former being strongly influenced by the proximity of canyons to shore and to riverine inputs, the latter primarily linked to fishing-activities, which can be quite intense in and around canyons due to the high productivity often associated with these features. Accumulation of fishing-related debris is mainly observed at the canyon heads and walls, where it can impact ecologically relevant communities that thrive in these habitats. Conversely, transport and accumulation of general waste and plastic along canyon axes can be related to different mechanisms, encompassing enhanced bottom currents, dense water cascading and turbidity currents, whose efficient transfer capacity is supported by ongoing evidence of large litter piles at great water depths. Global assessment of canyons exposure to riverine plastic inputs and fishing-related debris indicates varying susceptibility of canyons to litter, with Mediterranean canyons overall more exposed to both riverine and maritime litter contamination when compared to other ocean basins. However, considering that most of the canyons prone to receive large amounts of anthropogenic debris have not yet been surveyed, several knowledge gaps need to be filled to fully understand this issue.

Sediment transport mechanisms and downward particle fluxes in Blanes Canyon and their influence on cold water coral benthic communities

Puig, P.[1], Arjona-Camas, M.[2,3], Palanques, A.[1], Lo Iacono, C.[1], Bilan, M.[4], Cabrera, C.[1], Durán, R.[1]

[1] Institut de Ciències del Mar, Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain
[2] Departament de Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, Barcelona, Spain
[3] CEFREM-CNRS, Université de Perpignan Via Domitia, Perpignan, France
[4] University of Salento, Lecce, Italy

To investigate the sediment transport mechanisms and the composition of downward particle fluxes in the Blanes Canyon (NW Mediterranean), and their influence on suspension feeder cold water coral benthic communities, four instrumented mooring arrays were deployed at ~600 m water depth during winter and spring 2020. Two moorings equipped with currentmeters, turbidimeters and sediment traps were placed at a main canyon head and two identical ones were placed at the head of a canyon tributary, in regions characterized by narrow gorges and the presence of vertical canyon walls. The time series revealed that near-bottom currents were aligned with the canyon wall orientations and oscillated up- and down-canyon mainly at inertial frequencies. In the absence of major storms and river floods during the deployment period, the highest current velocities measured at both study sites were ~35 cm/s and directed up-canyon, although the residual flows in both monitored sites were predominantly down-canyon. Suspended sediment concentrations did not exceed 4 mg/L and they mainly increased during down-canyon flows, which contributed to a continuous and persistent transfer of suspended particles towards deeper parts of the canyon. The magnitude and the organic composition of the downward particle fluxes barely differed between monitoring sites, despite their different morphological context and distance from the coastline. This similarity presumably reflects the natural ambient conditions within the canyon during the Covid-19 lockdown, with the consequent reduction of the anthropogenic sediment resuspension caused by bottom trawling activities around the canyon head region. Overall, these time series reveal a complex interaction between local hydrodynamics and steep canyon morphologies, which ultimately affect the ambient suspended sediment transport throughout the canyon, potentially driving the settlement and development of benthic communities inhabiting submarine canyon walls.

Insights into understanding how internal waves control the shape of the continental margin

Marta Ribó[1], Joe O'Callaghan[2], Sally J Watson[3,4]

[1] Auckland University of Technology, AUT, New Zealand
[2] Oceanly Science, New Zealand
[3] National Institute of Water & Atmospheric Research (NIWA) Ltd/Taihoro Nukurangi, Te Whanganui-a- Tara/ Wellington, Aotearoa/New Zealand (NZ)
[4] University of Auckland/Waipapa Taumata Rau, Tāmaki Makarau/Auckland, Aotearoa/NZ

Internal waves (IW) propagate through the interior of the ocean shoaling and breaking over continental margins. IW are mainly caused by the tidal movement of the stratified ocean interacting with the seafloor topography and can reach heights of ~100 m and travel > 2000 km until finally breaking onto the continental margin. The shoaling of IW over the continental slope and shelf can influence the sediment dynamics, ultimately controlling the seafloor morphology along the continental margins.

Here we present a study where we integrate high-resolution multibeam bathymetry, ocean glider data, and hydrographic time series to determine whether IW shoaling and breaking across distinct seafloor morphologies drives differing sediment resuspension.

Our study is centred in the northeast region of Northland/Te Tai Tokerau, Aotearoa/New Zealand, where IW have been observed to propagate over the continental shelf, reaching amplitudes up to 100 m. This region has increasingly been affected by marine heat waves over the last decade. We hypothesise that changes in ocean stratification could modify IW dynamics and therefore the morphology of the shelf. The continental margin in northeast Northland is characterised by an open slope region that evolves into a shelf with incising canyons to the north. This makes the region an ideal natural laboratory to investigate how the continental margin morphology interacts with and responds to IW propagation and breaking. Our results will examine IW dynamics over different continental margin configurations (i.e., open slope vs submarine canyon incised margin, and concave vs convex slopes), to determine the interdependency between IW dynamics and a seafloor with diverse lithology and contrasting margin morphologies.

The bathypelagic community of Monterey Canyon

Robison, BH[1], Reisenbichler, KR[1], Sherlock, RE[1], Leitner, AB[1,2]

[1] Monterey Bay Aquarium Research Institute, USA
[2] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, USA

Bathypelagic communities have long been regarded as dilute and depauperate – difficult to study and hard to understand. Recent advances in undersea technology are changing that perception and the first comprehensive description of a bathypelagic community has revealed a rich and diverse biota. From 2003 to 2023 we used two deep-diving ROVs to conduct video surveys of the midwater fauna at depths between 1000 and 3500 m, at a site in the Monterey Canyon, off the central California coast. Analyses of the video data revealed a rich and diverse fauna dominated by gelatinous forms. In particular, the holopelagic polychaete Poeobius meseres was an important detritivore in the upper half of this depth range. As Poeobius abundance eventually declined with increasing depth, the abundance of larvacean particle feeders increased. In contrast, the relative numbers of crustacean suspension feeders, principally copepods and mysids, remained relatively constant. Medusae were most abundant and most diverse among the gelatinous predators, which also included ctenophores, and siphonophores. Chaetognaths occurred chiefly in the upper half of the depth range. Likewise, micronektonic fishes and squids were found principally in the upper bathypelagic region. While there is considerable overlap, the bathypelagic community can be separated into upper (1000 m to 2300 m) and lower (2400 m to 3300 m) zones, as well as a distinct and populous benthic boundary layer. Within the overall bathypelagic community is a complex web of trophic links involving many gelatinous predators which feed on both gelatinous and hard-bodied particle feeders, as well as on each other. Adapting to the bathypelagic habitat has yielded some striking and surprising transformations of familiar body forms and natural histories among taxa commonly found at shallower depths. The amount of organic carbon contained within the bathypelagic community is substantial but its ecological fate is still uncertain

Assessing the monitoring capacities of CMEMS (Copernicus Marine Environment Monitoring Service) to investigate dense shelf water cascading in submarine canyons of the Gulf of Lions, Western Mediterranean

Helena Fos[1,2], **Anna Sanchez-Vidal**[1], Xavier Durrieu de Madron[3], Suso Peña-Izquierdo[2], Laia Romero[2], Marc Cerdà-Domènech[1], Antoni Calafat[1], David Amblas[1]

[1] Universitat de Barcelona, Barcelona, Spain
[2] Lobelia Earth, Barcelona, Spain
[3] CEFREM-CNRS, Perpignan, France

Long-term time-series of deep-sea variables are fundamental baselines for assessing the natural patterns of ocean system variability, though they remain challenging as require uninterrupted funding and retention of trained personnel. The satellite era has revolutionized our ability to monitor and understand ocean dynamics and has provided us high resolution sea surface variables which can be projected at depth by applying adequate hydrodynamic models and data assimilation. This enables to reanalyse and forecast ocean dynamics and estimate past and future critical variables and changes in the deep sea. This is particularly important in a complex area such as submarine canyons where atmospherically-driven energetic hydrodynamics occur.

We have integrated the long-term near bottom data set (temperature and current speed) in the Cap de Creus and Lacaze-Duthiers submarine canyons in the Gulf of Lions with the physical reanalysis of the Mediterranean Sea at high resolution developed in the Copernicus Marine Environment Monitoring Service (CMEMS). This reanalysis of the Mediterranean Sea provides daily averaged data since 1987, with 1/24º latitude-longitude grid width, which corresponds to about a data point every 4 km in the Gulf of Lions. We have focused our efforts to validate the CMEMS model output on the intense dense shelf water cascading event recorded in 2012 that triggered near bottom current speeds above 1.2 m s-1 and temperature drops of 3ºC at 1000 m of water depth in the canyon axis. The reanalyses correlate very well with the in-situ observations of cascading waters, and provide a 3D view of the shelf water properties and how they evolve in time during the event, and allow investigate which are the main atmospheric and oceanographic factors behind the occurrence of this extraordinary process.

Between a rock and a hard place: when midwater animals bump into the benthos

Leitner, AB[1,2], **Sherlock, RE**[1], Reisenbichler, KR[1], Robison, BH[1]

[1] Monterey Bay Aquarium Research Institute, USA
[2] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, USA

Monterey Bay is bisected by the Monterey Submarine Canyon that ranges from hundreds to approximately 4000 meters in depth. The Monterey Bay Aquarium Research Institute has maintained a time series of mesopelagic observations for over 30 years and we have learned a great deal about the abundance and diversity of midwater animals. Many of these animals migrate vertically such that their daytime depth distribution differs markedly from the depths they occupy at night. These animals generally do not come into contact with the bottom; however, abrupt topographic features that shoal as steep cliffs can provide unique habitat where mesopelagic animals interact with the seafloor and its community. We studied the variation in abundance and composition of the animal community within 200 m of three different canyon walls using video, and report how these patterns changed over the diel cycle.

Influence of submarine canyons on long-term sedimentation dynamics in the northern Hikurangi Subduction Margin, New Zealand during the late Quaternary

Anthony Shorrock[1], Lorna Strachan[1], Philip Barnes[2], Greg Moore[3], Davide Gamboa[4], Rebecca Bell[5] Adam Woodhouse[6], Martin Crundwell[7]

[1] University of Auckland, New Zealand
[2] National Institute of Water and Atmospheric Research (NIWA), New Zealand
[3] University of Hawaii, USA
[4] CESAM, University of Aveiro, Portugal
[5] Imperial College, UK
[6] University of Bristol, UK
[7] GNS Science

Analysis of bathymetric, seismic, and sedimentological datasets obtained from the northern Hikurangi Subduction Margin (HSM) demonstrate the strong influence of gravity flows sourced from submarine canyons on the sedimentation regime of the region. Sediment cores obtained from International Ocean Discovery Program (IODP) Site U1520, retrieved during Expeditions 372B/375, preserve a ~110m-thick turbidite sequence (Unit I) that was deposited over the past ~45k yrs and is hypothesised to be primarily sourced from gravity flows originating in the Māhia Canyon and the Hikurangi Channel.

The shelf-incising Māhia Canyon is steep enough (2.7 – 3.5°) to allow flows to become supercritical. The exit of these high-energy and erosive flows from the confined mouth of the canyon onto the Hikurangi Trough floor are responsible for the formation of a field of large-scale erosional scours, which further transition into a field of cyclic steps orientated in the inferred direction of the Māhia Canyon-derived flows to the northeast of the canyon. The scale of these features are comparable to some of the largest globally recorded.

Sedimentation rates at Site U1520 exceeded 10 m/kyr during the Last Glacial Maximum (LGM), indicating that submarine canyon systems funnelled enormous quantities of sediment into the Hikurangi Trough during this period. The rapid increase in sedimentation during the LGM observed at Site U1520, and subsequent decrease during the Holocene, may be due to a threshold related to eustatic sea-level that controls the volume of sediment discharged by submarine canyon systems in the region. During the LGM, the head of the Māhia Canyon was directly connected to fluvial and vigorous coastal sediment transport systems, leading to a rapid and sustained increase in sediment flux for the duration of the lowstand. The recurrence interval for the emplacement of event beds was also significantly higher during the LGM (49 years) versus Marine Isotope Stage 1 (MIS1) (322 years), suggesting a much higher frequency of gravity flows in this more active glacial depositional environment. These findings provide new insights into how submarine canyon systems along the northern HSM operated during the late Quaternary, and how they responded to changing environmental conditions.

Linking East Australian Current dynamics and submarine canyon geomorphology to marine ecosystem hotspots

Bernadette Sloyan and co-collaborators

CSIRO Environnent, Australia

The East Australian Current (EAC) influences the climate and marine industries for more than half of Australia's population, from Brisbane to Sydney, Melbourne and Hobart. The strongest and most coherent part of the EAC lies to the east of the continental shelf, where it interacts with the shelf break and slope, driving sporadic upwelling of colder, nutrient rich waters. Of particular interest is the role played by various deep canyon systems – North Solidary Island and Richmond canyons - that incise the shelf in shaping the physical and ecological environment of the coastal waters of eastern Australia, in a region where the EAC is most coherent. These canyon systems are largely unexplored, despite their size and potential influence on coastal ecosystems and the strong gradients in vertical relief. We will compare the currents, particularly the shoreward flow and biota in two canyons with smaller adjacent canyons and with the famous Leeuwin Current-Perth Canyon.

This talk will describe the east Australian canyons that are our focus and provide details of the first comprehensive geomorphology, ocean physical/biogeochemical and biological survey in the North Solitary Canyon in the Central Eastern Marine Park (part of the Temperate East network) that will occur in June 2024.

Observations of the internal tide at the head of Cook Strait Canyon, Aotearoa New Zealand

Craig Stevens[1,2], Alain De Verneil[1], Cynthia Bluteau[3], Peter Russell[4] and Jasmin McInerney[1]

[1] NIWA National Institute for Water and Atmospheric Research, Wellington, New Zealand.
[2] Dept. Physics, University of Auckland, New Zealand.
[3] Dept. Fisheries and Oceans, Canada.
[4] Dept. Physics, University of Otago, New Zealand.

Cook Strait canyon is remarkable in that its head is close by the Cook Strait Te Moana o Raukawa narrows and so influenced by the substantial tidal flows found in the area. Here we describe some recent CTD and ADCP observations of the varying baroclinic structure near the head of the canyon (600 m depth contour). The data cover a semi-diurnal tidal cycle. Over this period mid-water column isotherms are displaced by around 200 m. Overturning structure is observed at stages through the cycle and this correlates with oxygen variability. Analysis considers both the finescale parameterised mixing along with wider implications for the region.

Carbon cycling in the benthic food web of a river-connected, higher-energy submarine canyon

Chueh-Chen Tung[1], Yu-Shih Lin[2], Jian-Xiang Liao[3], Tzu-Hsuan Tu[2], James Liu[2], Li-Hung Lin[4], Pei-Ling Wang[1], **Chih-Lin Wei**[1]

[1] Institute of Oceanography, National Taiwan University, Taipei, Taiwan
[2] Department of Oceanography, National Sun Yat-sen University, Kaohsiung, Taiwan
[3] Taiwan Power Research Institute, Taiwan Power Company, Taipei, Taiwan
[4] Department of Geoscience, National Taiwan University, Taipei, Taiwan

The Gaoping Submarine Canyon (GPSC) located off Southwest Taiwan has been extensively researched for its distinctive geological features and diverse biological communities. However, the understanding of carbon cycling at the sediment-water interface remains limited. To address this gap, this study utilizes field data collected from 2014 to 2020 and employs the Linear Inverse Model (LIM) to reconstruct the benthic food web (i.e., carbon flows through different stocks), specifically tracking carbon flows through various stocks, in both the head of GPSC and the upper Gaoping slope (GS). Although seasonal variation in organic carbon (OC) stocks was not significant, the biotic and abiotic OC stocks were notably higher on the slope compared to the canyon, except for the bacteria stock. Both habitats showed similar sediment oxygen utilization, but the magnitude and distribution of OC flow in the food web were distinctively different.

In the canyon, despite a significant input flux of 1265.39 mg C/m2/d, a substantial 84% of the carbon flux exited the system, while only 14% was buried. On the slope, 74% of the OC input (105.46 mg C/m2/d) was buried, and only 11% exited the system. Notably, bacteria processes played a significant role in carbon flows within the canyon, while the upper slope food web exhibited stronger interactions among metazoans, indicated by higher flows between meiofauna and macrofauna compartments.

The application of network indices based on LIM outputs revealed that the canyon head had a higher total system throughput (T..) and total system through flow (TST), indicating greater energy flowing through the system. On the other hand, the slope exhibited a significantly higher Finn cycling Index (FCI), average mutual information (AMI), and longer OC turnover time, suggesting a more mature ecosystem with higher energy recycling. By integrating field data into a food web model, this study offers valuable insights into the fate of OC cycling in an active submarine canyon, shedding light on the often overlooked benthic communities.

Sculpting a land-detached large-scale canyon-channel system: influence of margin processes before, during and after incision

Lotte Verweirder[1], David Van Rooij[1], Aggeliki Georgiopoulou[2]

[1] Department of Geology, Ghent University, Krijgslaan 281 (S8), 9000 Ghent, Belgium
[2] Ternan Energy, St John's House, St John's Street, Chichester, PO19 1UU, United Kingdom

The land-detached Gollum Channel System (GCS) is one of very few large-scale canyon-channel systems on the Northwest European margin and thought to be of high importance in both along-slope and downslope sediment transport processes in the Porcupine Seabight basin. It is, however, unknown when this system was formed and how active it has been throughout its evolution, making it difficult to assess its regional impact. Well data integrated with airgun seismic reflection data were used to build a seismic stratigraphy (Cretaceous to present) for the GCS for the first time. We found that, contrary to what was thought before, the GCS was formed before Quaternary glaciations occupied the continental shelf and its origin is tentatively associated to a phase of Northeast Atlantic margin tilting in the early Pliocene. Each of the channels that make up the GCS was initiated by incision from erosive downslope gravity flows originating on the Celtic Sea Shelf. Gravity flows from Quaternary glacial processes reused the channels and mostly bypassed the upper slope or contributed to the channel fill, though some were capable of less severe erosion of existing channel flanks and incision of several smaller channels. Additionally, we show that this margin was incised by erosive gravity flows on several occasions through time and that these incisions seem to follow preferential pathways. Interaction with along-slope bottom currents from the start of the Quaternary onwards was crucial to distribute sediments and nutrients to sediment drifts and cold-water coral mounds further north (downstream) along the Irish margin.

The form and history of submarine canyons offshore Taranaki, Aotearoa New Zealand

Lea Bertrand[1,2], **Sally J. Watson**[1,3], Jess I.T. Hillman[4], Suzanne Bull[4]

[1] National Institute of Water & Atmospheric Research (NIWA), Aotearoa New Zealand
[2] Ecole Nationale Supérieure des Techniques Avancées de Bretagne (ENSTA Bretagne), Brest, France
[3] Institute of Marine Science, University of Auckland, Auckland, Aotearoa, New Zealand
[4] GNS Science, Lower Hutt, Aotearoa New Zealand

Submarine canyons are important in the assessment of coastal and marine hazards as many dynamic geological processes, including submarine sediment flows and large landslides frequently occur within them. A new bathymetric dataset acquired in 2020/21 offshore Taranaki has enabled the detailed mapping of submarine canyons in this area for the first time. Merging multibeam data acquired on four different surveys (including both dedicated surveys and transit lines) enabled the creation of a comprehensive bathymetric and backscatter grid at 25 m resolution. These data reveal 18 new canyons that extend from the continental shelf break at ~200 m to abyssal depths of ~1300 m. The maximum canyon length (streamwise distance) is at least 99 km, with channels likely extending beyond the surveyed region. Using these data, we conducted a geomorphological analysis, including computation of different morphometric parameters for each canyon (including slope, sinuosity and aspect ratio etc.). The canyons show variable sinuosity, with higher sinuosity segments being generally across the lower slope and deeper across the continental shelf. Seafloor morphology was then analysed in conjunction with extensive subsurface marine geophysical data, including newly acquired high-resolution seismic and sub-bottom profiler (TOPAS) data and industry acquired seismic reflection data.

These data provide the first glimpse into the form and structure of the modern Taranaki canyon system, and insights into their evolution, including interactions with mass slope failure processes. This study allows us to further our understanding of paleo- and modern shelf processes in the region, and investigate the interplay between submarine canyon incision, submarine landslides and sea-level fluctuations.

Seasonal Variations of Nonlinear Internal Waves and Sediment Transport in the Northeastern South China Sea

Weihan Ruan[1], Yanwei Zhang[1], Danny Lyu[1], Zhifei Liu[1], Yulong Zhao[1], Xiaodong Zhang[1], Chen Ling[1], Pengfei Ma[1], Xun Yu[1], Jingwen Zhang[1]

[1] State Key Laboratory of Marine Geology, Tongji University

Nonlinear internal waves (NLIWs) are ubiquitous and unique in the South China Sea, which are featured with large amplitude, narrow waveform, fast current velocity and intense dissipation. In particular, the shoaling processes of NLIWs on the shelf after their long-distance propagation from Luzon strait have been acknowledged as the key to the formation of sediment waves. However, their critical contribution to sediment resuspension and transportation is not yet investigated quantitatively on seasonal scales. In this study, we deployed an integrated mooring system at a water depth of 335 m on the shelf in the northeastern South China Sea. The mooring system was equipped variable instruments and probes to record current velocity, temperature, salinity, and sediment concentration with high temporal resolution in a whole year.

Two typical formats of NLIWs are categorized according to the measurements: A-waves (B-waves) are characterized by larger (smaller) amplitude correspondent to ebb (flood) barotropic tidal current. Fortnight-cyclic and interseasonal variations are recognized from the occurrence rate and variant amplitudes for the two types of NLIWs. Further examination revealed that the barotropic tides regulate the cyclic temporal variations. Moreover, the enhanced flows induced by mesoscale eddy and Kuroshio intrusion were found to play a significant role in the occurrence rate by diverting the propagation pathway of NLIWs.

These large-amplitude NLIWs can induce intense sediment resuspension via high shear variance, resulting in notable lateral fluxes of sediment near the bottom. The lateral transport of sediments induced by NLIWs during the year-round period was about 1.66×107 tons, which is comparable to the total sediment transport caused by extreme events such as typhoons.

How does plastic litters aggregate in submarine canyons? A field scale simulation study

Jingping Xu[1], Yuping Yang[1], Kaiqi Yu[1], Dawei Wang[2], Guangfa Zhong[3], Minghan Wang[4] and Benjamin Kneller[5]

[1] Southern University of Science and Technology, Shenzhen 518055, China
[2] Institute of Deep-sea Science and Engineering, Sanya 572000, China
[3] Tongji University, Shanghai 200092, China
[4] University College of London, London WC1E 6BT, United Kingdom
[5] University of Aberdeen, Aberdeen AB24 3UE, United Kingdom

Manned submersible dives in 2018 and 2020 in the northwest South China Sea encountered substantial amounts of plastic litters aggregated at the base of cyclic steps (stair-like morphological features) along the floor of a submarine canyon. A variety of hypotheses have been proposed to explain the aggregation processes of these plastic litter piles. One such postulated mechanism is the transportation and aggregation of by gravity-driven flows such as turbidity currents that are known to move large volume of sediment and particulate matter through submarine canyons. Internal hydraulic jumps are likely to occur when turbidity currents flow pass morphological sharps such as cyclic steps. In this study, we run simulations with field-scale bathymetry to investigate the relationship between the occurrence of internal hydraulic jumps and the locations and sizes of the plastic litter piles found in the canyon. Comparison of the simulation results with observed distribution of the plastic aggregation in the canyon shows that turbidity currents are a plausible forcing that is responsible for aggregating those plastic litters. Additionally, it is found that the small ramp at the downstream end of a cyclic step provides a necessary blocking effect for plastic litter accumulations, inhibiting the downstream movement of plastic litter after hydraulic jumps.

Observation evidences on typhoon-triggered landslide in the submarine canyon

Yiing Jang Yang[1], Barry B. Ma[2], Linus Chiu[3], and Wen-Hwa Her[1]

[1] Institution of Oceanography, National Taiwan University
[2] Applied Physics Laboratory and School of Oceanography, University of Washington
[3] Institute of Undersea Technology, National Sun Yat-sen University

Typhoons are most active in the Northwest Pacific subtropical ocean, where Taiwan is located. Annually, Taiwan experiences the impact of approximately 3 to 4 typhoons making landfall. The arrival of a typhoon and accompanying southwesterly flow, not only precipitates intense rainfall but also induces the rivers to discharge turbid, sediment-laden waters into the ocean. A duo of moorings, containing an acoustic Doppler current profiler (ADCP) and a bottom pressure recorder (BPR), were deployed at a depth of 360 meters within the Kaoping Submarine Canyon, located to the southwest of Taiwan. Upon analysis of the observational data, a notable occurrence was observed during the landfall of Category 3 Typhoon Sepat in Taiwan. The deluge of heavy rainfall resulted in an escalated discharge from the Kaoping River, subsequently instigating a hyperpycnal flow within the estuarine confines. This flow, in conjunction with the tidal current, has the potential to carry surface-warmed water to a depth of 360 meters. However, this intricate interplay of forces triggered a landslide event, which resulted in the displacement of the BPR mooring into the deeper ocean. Comprehensive results will be presented during the meeting.

Change in subaqueous debris flow and their deposits with or without gravel: an experimental study

Miwa Yokokawa[1], Noriyuki Yuasa[1], Akihiro Shoda[1], Hiroshi Kiyosato[1], and Yuto Kanezaki[1]

[1] Osaka Institute of Technology

Subaqueous debris flows and turbidity currents are important sediment transport phenomena and have a significant impact on submarine infrastructure. We are currently conducting experiments to gain basic knowledge on the effects of gravels on high mud content flows.

The experimental conditions of Ilstad et al. (2004) were used as a reference, and gravel was mixed with that condition. The ratios of water and clay to entire slurry were fixed at 35wt% and 32.5wt% respectively, and the remaining 32.5% by weight was varied in three ways: sand only (0% gravel), 5wt% gravel, and 15wt% gravel. Kaolinite (0.4 μm) was used as clay, silica sand (330 μm) as sand, and commercially available beach gravel (3-5 mm) as gravel. These materials were mixed well and poured into a submerged flume 700 cm long, 8 cm wide, 50 cm high, and with a slope of 6 degrees.

As a result, when gravels were added, the flow was accelerated along the way, and the time required to flow 7 m was significantly shortened (21 s for 0% gravels, 15 s for 5% gravels, and 16 s for 15% gravels). The distribution of sediments after the flow also differed depending on the presence or absence of gravels, with the gravels being deposited further upstream of the stream.

Sediments were collected from just below the surface of the sediments and near the bottom. The mud content was higher near the bottom than just below the surface in the 0% gravel area. In the case of 5% gravel, the mud content was not much different between just below the surface and near the bottom, while in the case of 15% gravel, the mud content was higher just below the surface than near the bottom. This suggests that when no gravel was added, the plug flow structure was more pronounced, so that it was difficult for flow acceleration to occur. On the other hand, when gravels are added, it is predicted that the settlement of the gravels will quickly break the plug flow structure, and the entrainment of ambient water will easily begin.

Reference: Ilstad, T. et al., 2004, Marine Geology, 213, 415-438.

Morpho-depositional characteristics of a large downstream-narrowing submarine canyon (Xisha Trough) in the South China Sea

Guangfa Zhong[1], Yongxian Guan[2], Liaoliang Wang[2]

[1] State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China
[2] Guangzhou Marine Geological Survey, Guangzhou 511458, China

Submarine canyons are formed mainly by turbidity currents in continental margins. Typically, they widen downstream, leading to less erosion and more sedimentation. However, some submarine canyons narrow downstream due to various reasons. How turbidity currents respond to such a downstream-narrowing morphology remains unclear. Here we report our novel findings from the Xisha Trough submarine canyon (XTSC) in the northwestern South China Sea by analyzing the multibeam bathymetric and two-dimensional seismic data. The XTSC is a slope-confined submarine canyon that stretches ~425 km in length in a 1200 to 3300 m water depth. The average thalweg gradient of the canyon is 4.6/1000. The U-shaped canyon is characterized by its downstream narrowing and deepening morphology, with canyon floor width decreasing downstream from 25 km to 4-5 km and canyon depth increasing from tens of meters to approximately 1000 meters. Seismic stratigraphic interpretation reveals that the canyon began in the late Miocene, and has persisted for over 10 million years. The canyon infillings exhibit two distinct seismic facies, marked by high-amplitude and transparent reflections, which are interpreted as turbidites and debrites or mass-transport deposits, respectively. The thickness of canyon fills decreases downstream, with the lower reach being only 1/3 as thick as the upper reach. We suggest that the narrowing downstream topography of the canyon may have resulted in the continuous acceleration of turbidity currents flowing through the canyon, ultimately leading to reduced sedimentation and intensified erosion downstream. This downstream-narrowing effect may represent an important mechanism for turbidity currents' self-acceleration and self-sustenance, which has important significance in understanding the formation and evolution of similar submarine canyons or canyon segments.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