Cruise Report

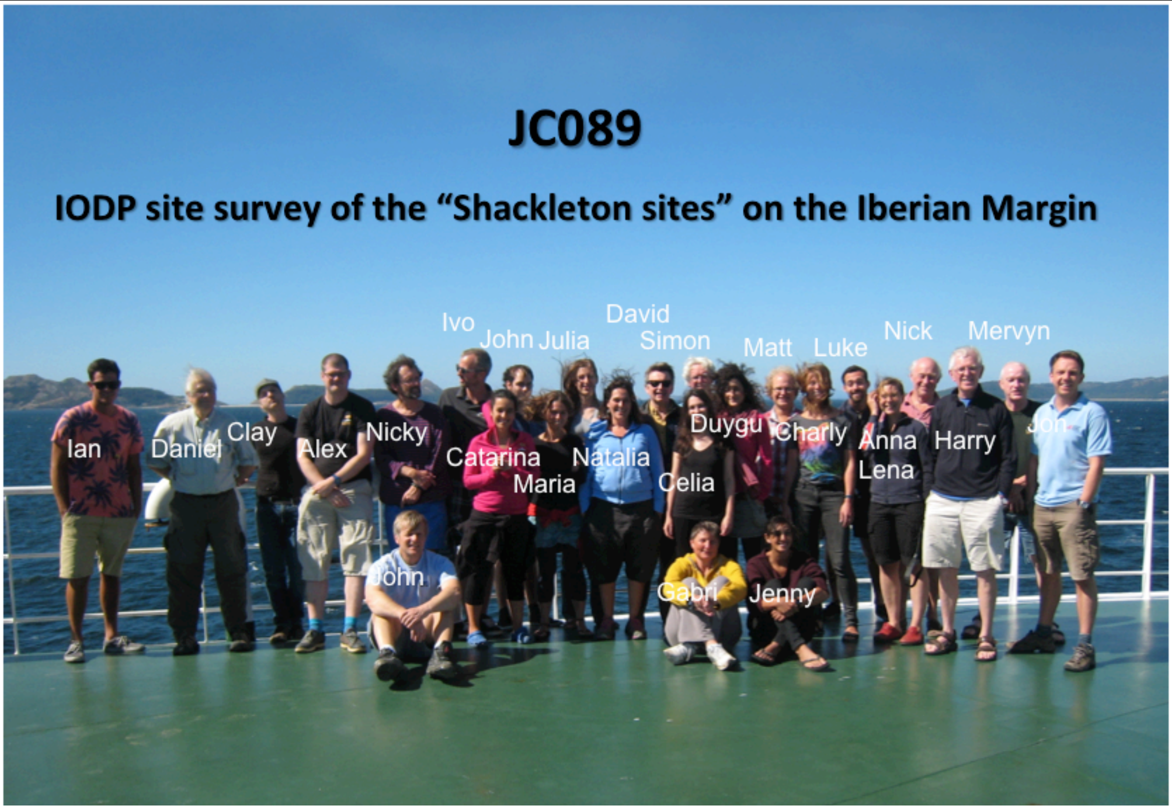
JC089
RRS James Cook
Southampton-Vigo-Vigo
25 July – 30 August, 2013

IODP Site Survey of the Shackleton Sites, SW Iberian Margin

David Hodell, Principal Scientist
Harry Elderfield, co-PI (Geochemistry)
Mervyn Greaves, co-PI (Geochemistry)
Nick McCave, co-PI (Sediment Coring)
Luke Skinner, co-PI (Sediment Coring)
Alexander Thomas, co-PI (Water Column)
Nicky White, co-PI (Geophysics)
and the JC089 Scientific Party*

*see page 4 for list of members of the scientific party

Publication date: 20 July 2014
Keywords: James Cook 089, Southwest Iberian Margin, IODP site survey, geophysics, cores, water chemistry
Issuing Organisation: Department of Earth Sciences, University of Cambridge



Frontispiece: JC089 Shipboard Scientific Party

Table of Contents

1. Abstract

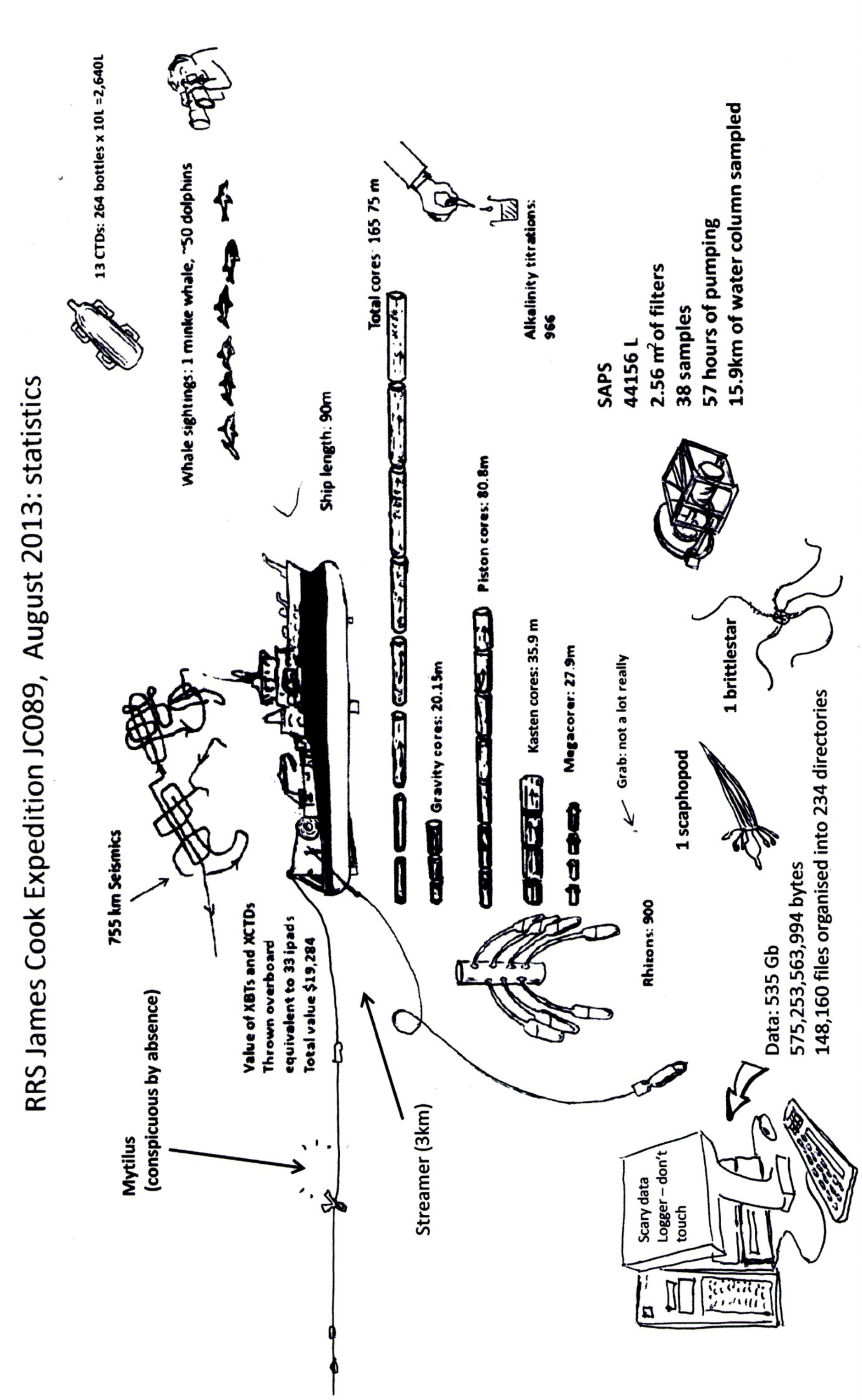
Cruise JC089 of the RSS *James Cook* set sail from Vigo, Spain, on 04 August 2013. The objectives were to collect geophysical data, water column samples, and sediment cores to support a proposal under consideration by the Integrated Ocean Drilling Program (IODP 771-Full) to drill a series of sites on the SW Iberian Margin. The primary survey area was the Promonotorio dos Prinicipes de Avis (PPA), a topographic feature elevated above the Tagus Abyssal Plain.

A total of 755 line kilometres of seismic reflection profiles were acquired using a 3-km streamer and a small airgun source consisting of a generator-injector (GI) gun. Data quality was generally good with penetration of 3–4 seconds two-way travel time with excellent resolution. The resulting set of crossing lines provides the survey data needed to support the IODP proposal 771-Full. An important by-product of this survey is seismic imaging of the water column (i.e., seismic oceanography), which was calibrated by a combination of disposable hydrographic probes and CTD casts. Multibeam bathymetry and 3.5 kHz echosounder data were collected continuously during the seismic survey.

In total, 13 CTD casts were made using a trace metal free system to characterize the physical and chemical properties of water masses on the Iberian Margin. The data are useful for interpreting the water-column seismic profiles and for groundtruthing palaeoceanographic proxies preserved in surface sediment. Water was collected at 13 stations using 10 liter Niskin bottles, totaling 246 bottles from which subsamples were taken for isotopic and elemental analysis. Large volume *in-situ* filtration was carried out at 6 stations using Challenger Oceanic Stand Alone Pumps (SAPs) to capture both suspended and sinking particles in the water column. Radiocarbon and geochemical analysis of the filtered samples will be used to determine the age, source, and transport of particles on the Iberian Margin.

Sediment cores were acquired along a bathymetric transect to meet IODP site survey requirements and to study sedimentary processes (e.g., sediment provenance and focussing), bioturbation, and calibrate geochemical and sedimentological proxies on the Iberian Margin. We recovered 10 piston cores, 12 box cores, 10 kasten cores, 4 gravity cores, 13 megacores, and 1 grab sample. The long cores span the last deglaciation and range in water depths from 600 to 4670 m, constituting as yet one of the most complete vertical transects of sediment cores from a continental margin. We will use the cores to reconstruct bathymetric transects of geochemical properties (e.g., oxygen isotopes, Mg/Ca, benthic $\delta^{13}C$, radiocarbon) and infer past changes in water mass distributions from the last glacial period through the Holocene.

Oxygen, pH, and redox gradients in sediment pore waters were determined using micro-electrodes inserted into Megacore tubes. Interstitial waters were sampled directly from the Megacores at 1-cm intervals using Rhizon soil moisture samplers. A total of 900 pore water samples were collected and alkalinity measurements were made onboard for each sample.



Cartoon of JC089 accomplishments (credit: Simon Crowhurst)

2. Cruise personnel:

Scientific Party:

1. Gabriela Carrara	IPMA	Geophysics
2. Catarina Cavaleiro	IPMA	Water chem./coring
3. Henry Elderfield	University of Cambridge	co-PI Geochemistry
4. Simon Crowhurst	University of Cambridge	Sediment coring
5. Maria De La Fuente	ICM CSIS Barcelona	Geochemistry
6. Matthew Falder	University of Cambridge	Geophysics
7. Julia Gottschalk	University of Cambridge	Sediment coring/MMO
8. Anna Lena Grauel	University of Cambridge	Geochemistry/MMO
9. Mervyn Greaves	University of Cambridge	Geochemistry
10. David Hodell	University of Cambridge	Prinicpal Scientist
11. Clayton Magill	ETH Zurich	Coring/SAPs
12. Nick McCave	University of Cambridge	co-PI Sediment coring
13. Jenny Roberts	University Cambridge	Sediment coring
14. Daniel Montlucon	ETH Zurich	Coring/SAPs
15. John Nicolson	University of Cambridge	Sediment coring/MMO
16. Celia Santos	IPMA	Sediment coring
17. Duygu Sevilgen	MPI MM and University of Cambridge	Geochemistry (microelectodes)
18. Charlotte Schoonman	University of Cambridge	Geophysics
19. Luke Skinner	University of Cambridge	co-PI Sediment coring
20. Alexander Thomas	University of Edinburgh	co-PI Water chemistry
21. Natalia Vazquez Riveiros	University of Cambridge	Sediment coring
22. Nicholas White	University of Cambridge	co-PI Geophysics

MMO = Marine Mammal Observer

Technicians:

1. Ian Murdoch	NMF Sea Systems	Sediment coring
2. Thomas Robert	NMF Sea Systems	Sediment coring
3. Jon Seddon	NMF Sea Systems	IT, underway systems
4. Neil Sloan	NMF Sea Systems	Sediment coring/Geophysics
5. Yvo Witte	NIOZ	Sediment coring
6. John Wynar	NMF Sea Systems	CTD/SAPs
7. Minerva Alegre	CSIC	Geophysics
8. Ezequiel Gonzalez	CSIC	Geophysics

Crew:

1. Sarjeant	Peter Charles	Master
2. Newton	Peter William	C/O
3. Macleod	Iain	2/O
4. Munro	Paul Graham	3/O
5. Smith	Peter	3/O
6. Hinds	Matthew	C/E
7. Kemp	Christopher Martin	2/E
8. Porrelli	Lawrence	3/E
9. Slater	Gary	3/E
10. Ulbricht	Sebastian Martin	ETO
11. Bullimore	Graham	PCO
12. MacDonald	John Ewan	CPOS
13. Maclean	Andrew	CPOD
14. Smyth	John Gerard	ERPO
15. Allison	Philip	POD
16. Day	Stephen Paul	SG1A
17. Sims	Kenneth Neil	SG1A
18. Welton	Jarrod David	SG1A
19. Mackenzie	David	SG1A
20. Haughton	John	H/Chef
21. Link	Walter John Thomas	Chef
22. Mingay	Graham Malcolm	Stwd
23. Piper	Carl	A/Stwd

IPMA = Instituto Português do Mar e da Atmosfera, Lisbon, Portugal.
ETH = Eidgenössische Technische Hochschule Zürich, Switzerland.
MPI MM = Max Planck Institute of Marine Microbiology, Bremen, Germany.
NMF = National Marine Facilities, National Oceanographic Centre, Southampton.
NIOZ = Royal Netherlands Institute for Sea Research, Netherlands
CSIC = Spanish National Research Council

3. Scientific objectives

The SW Iberian margin is noted for providing high-fidelity records of millennial-scale climate variability for the last several glacial cycles (Shackleton et al., 2000, 2004; Martrat et al., 2007; Hodell et al., 2013). Piston cores from the Iberian Margin have yielded a detailed record spanning the last 420 ka. In order to expand this record deeper in time, an international group of 16 proponents prepared and submitted IODP Proposal 771-Full in April 2010 (Hodell et al., 2010). The IODP proposal outlines plans for a 56-day expedition to drill six sites along a depth transect to recover sediments from the latest Miocene to Recent.

The site survey package for 771-Full was reviewed by the IODP Site Survey Panel (SSP) in July 2010 and Feb 2011. Only one of the sites proposed was classified as ready to be drilled (1Aa). All others were classified as 2Cc (i.e., substantial items of required data are not in the Data Bank and not believed to exist, and data do not image target adequately). Recognizing that the proposal could not be advanced without additional site survey information, NERC provided support for Cruise JC089 aboard the RSS *James Cook* to collect the deficient seismic and sediment data needed to underpin IODP Proposal 771-full.

Cruise objectives:

(i) Acquire high-resolution seismic reflection profiles and swath bathymetry to fulfill the site survey requirements and recommendations of IODP's Site Survey Panel. The seismic data will also be used to image large-scale oceanographic features and mixing processes in the water column, such as water-mass boundaries, eddies, and meddies.

(ii) Acquire CTD data and water samples to characterize the physical and chemical properties of water masses on the Iberian Margin, which is needed to interpret the water-column MCS profiles (e.g., constructing synthetic acoustic impedance profiles) and for groundtruthing palaeoceanographic proxies in surface sediment.

(iii) Acquire sediment cores along a bathymetric transect to study sediment processes (e.g., sediment provenance and focussing), bioturbation, and to calibrate geochemical and sedimentological proxies on the Southwest Iberian Margin.

(iv) Utilize new water column and pore-water analyses to test the underlying rationale and calibration of a set of key trace-element and isotope proxies. This will include an assessment of early diagenetic influences on the chemistry of infaunal versus epifaunal benthic foraminifer species, and will target proxies for carbonate chemistry (e.g., B/Ca), nutrient concentrations (e.g., $\delta^{13}C$, Cd/Ca) and redox state (U, Mo, Mn, V, Fe). A key goal will be to combine these proxies to interpret the down-core records of orbital and millennial-scale climate variability of the late Pleistocene.

4. Cruise Overview

The cruise was mobilized from the National Oceanographic Centre (NOC), Southampton on 25-27 July 2013 (Fig. 1). We were detained in Southampton for repairs to seawater cooling pipework. The ship left port at 10:00 on 28 July 2013 for passage to Vigo, Spain, arriving at 06:00 on 31 July 2013. In Vigo, the CSIC winch, seismic streamer, and recording gear were loaded onto ship, which completed the mobilization phase of JC089. We were detained in Vigo awaiting delivery of a new hydraulic component of the deck crane that had to be installed and load-tested. Had this not occurred we would have been able to leave by 20:00 on 1st August. However, the Chief Engineer was pronounced sick and a replacement had to be flown out from UK, occasioning further delay. We finally departed Vigo at 20:00 on 04 August 2013, which marked the start of science operations. The first two stations at the "Morena sites" served as a shakedown for coring procedures and equipment. The remainder of the cruise was spent conducting geophysical surveys and collecting water and sediment samples on the Promonotorio dos Principes de Avis to the southwest of Lisbon (Fig. 2). This spur is located on the continental slope of the southwestern Iberian margin and is elevated above the Tagus abyssal. After 22 days at sea, the RRS *James Cook* returned to Vigo at 18:05 on 26 August 2013. Demobilisation in Vigo commenced the following morning at 08:00.

4.1 Geophysics

Acquisition and processing of high-resolution seismic reflection data were a primary goal of the survey. Because of the potential occurrence of Mass Transport Deposits (MTDs) and local faulting in the region, the IODP Site Survey Panel requested two orthogonal high-resolution multi-channel seismic (MCS) crossing lines at each of the proposed sites. We collected ~755 km of seismic lines (Fig. 4) with a seismic acquisition system consisting of two air guns (360 in^3) operated at 3000 psi and a 3-6 km Sercel streamer, which was hired through a barter agreement from the Spanish National Research Council (CSIC). CSIC also provided technical support (Minerva Alegre and Ezequiel Gonzalez) and a chase vessel (*Mytilus*) for the streamer that was required for surveying in the shipping lanes east of -10°W. There were significant problems with using two air guns and the bulk of the survey was acquired using a single gun. Despite this technical problem and weather issues, the data quality were good. Penetration of 3–4 seconds two-way travel time was achieved at high fold with excellent resolution.

Unfortunately, the chase vessel (*Mytilus*) contracted by CSIC was not fit for purpose and was unable to remain at sea even under moderate weather conditions. This meant we could not survey the shallower sites located in the shipping lanes east of ~10°W longitude. Instead we will request/purchase data from an industry geophysical firm (TGS, Norway) who possesses multi-channel seismic lines in the area.

The second objective of the geophysical survey was seismic oceanography – i.e., identifying larger-scale oceanographic features (e.g., water-mass boundaries and fronts) associated with the principal water masses on the margin: upper and lower Mediterranean Overflow Water (MOW) between 600 and 1500 m, recirculated Northeast Atlantic Deep Water (NEADW) below 1500 m, and southern-sourced Lower Deep Water (LDW) below 3000 m. The large temperature and salinity contrasts, especially MOW/NEADW, are particularly well suited for imaging the water column using MCS

(Sheen et al, 2009; Pinheiro et al., 2010). The water-column seismic data were calibrated using a combination of disposable hydrographic probes and CTD casts.

Multibeam bathymetry was collected along seismic lines to construct a bathymetric map showing the depth and shape of the surrounding seafloor at each of the proposed drilling sites.

4.1.2 Sediment coring

A variety of coring systems were employed during JC089 including the SMBA box corer, McCave Kasten corer, NIOZ piston corer, gravity corer, OSIL Megacorer (http://www.osil.co.uk), and a grab sampler. We recovered 10 piston cores, 12 box cores, 10 kasten cores, 4 gravity cores, 13 megacores, and 1 grab sample. The science objectives were far exceeded for sediment coring operations. In addition to the 7 primary coring targets, we obtained sediment cores from 5 additional shallower sites to complete a depth transect ranging from 405 to 4670 meters of water. In addition to addressing the IODP site survey requirements, the cores will be used to study sediment processes (e.g., sediment provenance and focussing), bioturbation, and calibrate geochemical and sedimentological proxies on the Iberian Margin.

4.1.3 Pore water geochemistry

Approximately 900 samples of pore waters were extracted from box-, multi-, and piston-cores using Rhizon samplers (Rhizosphere Research Products, http://www.rhizosphere.com/). Megacores at each station were sampled at 1-cm resolution and alkalinity was measured onboard ship. Pore-water oxygen and pH gradients were determined by inserting micro-electrodes into the Megacore tubes.

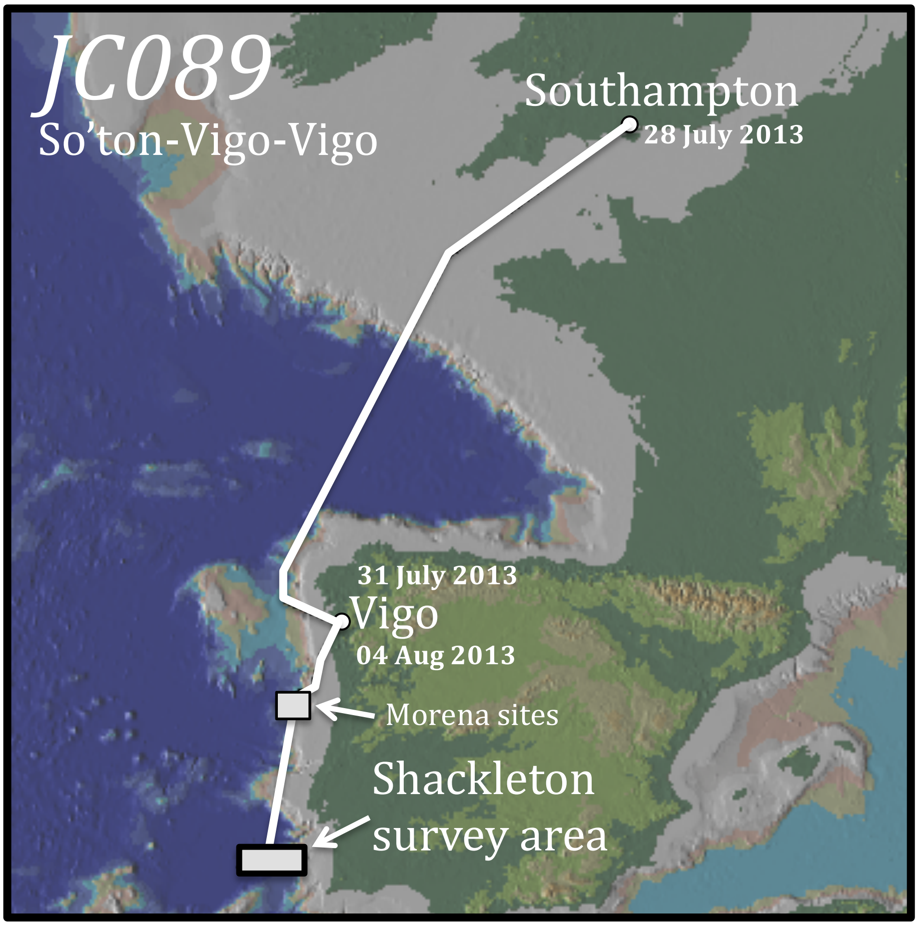


Figure 1. General cruise track of JC089. Mobilisation of most equipment and supplies occurred in Southampton followed by a transit to Vigo to load the seismic gear, streamer, and winch. The two Morena sites served as a shakedown for coring equipment and procedures. The main area of operation was located to the southwest of Lisbon.

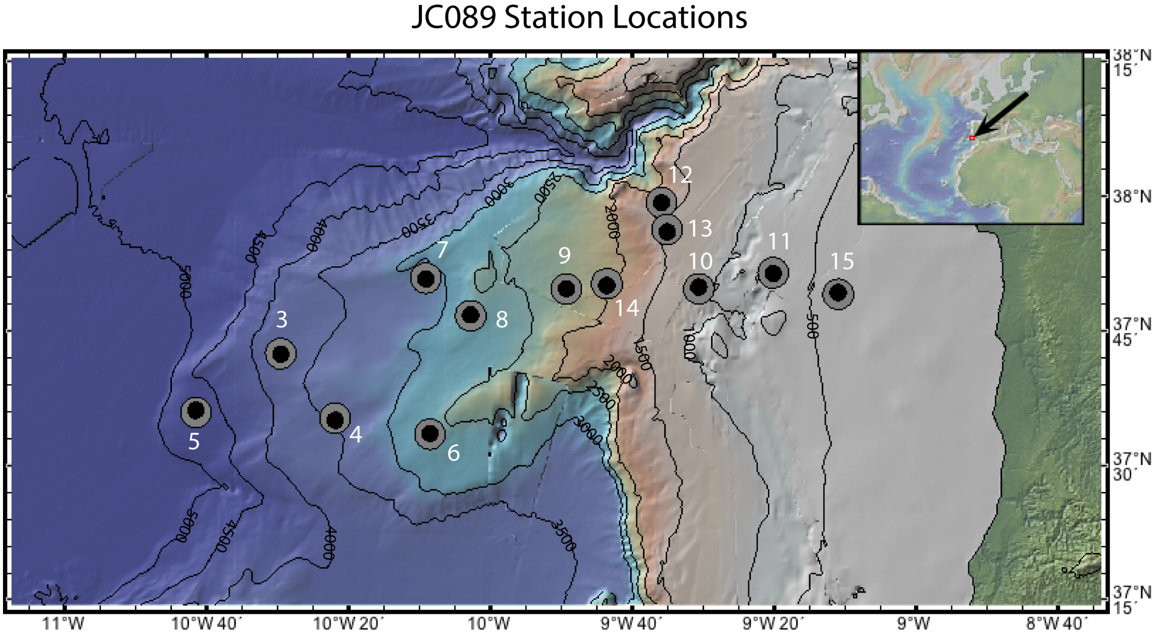


Fig. 2 The survey area is located on a spur, the Promonotorio dos Principes de Avis, along the continental slope of the southwestern Iberian margin, which is elevated above the abyssal plain and influence of turbidites. Fifteen stations were occupied during the cruise forming a depth transect of sites from 405 m in the east to 4670 m in the west (see Table 1 for coordinates and water depths).

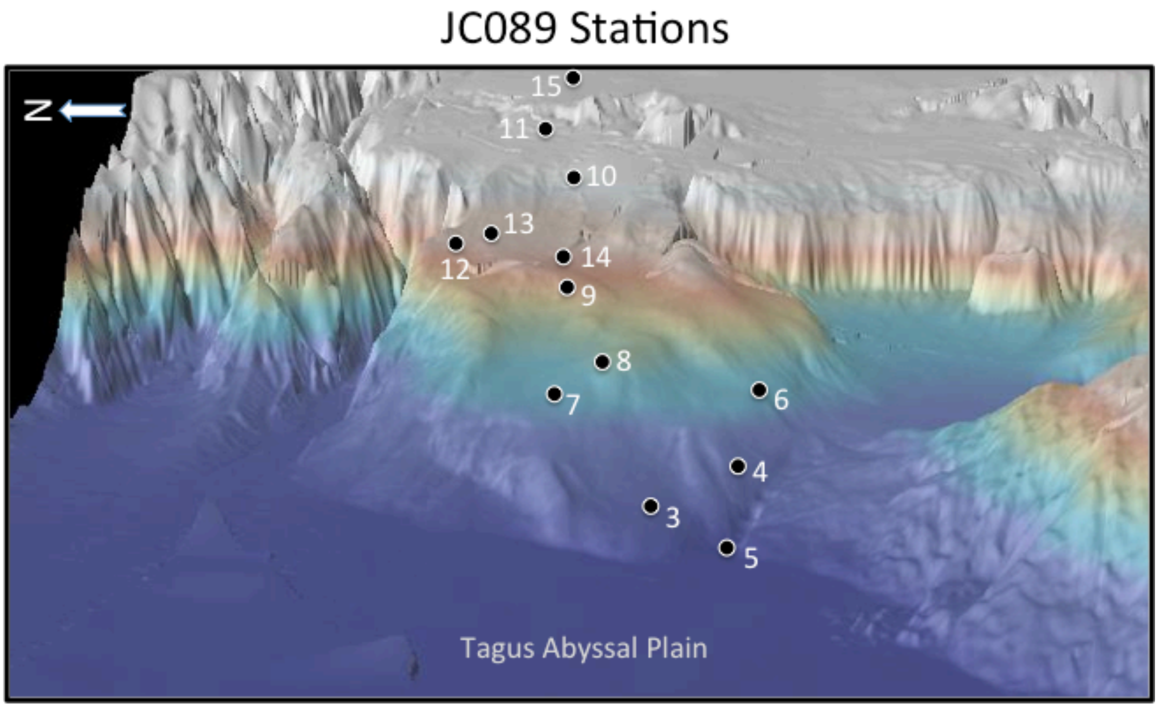


Figure 3. Depth distribution of coring locations on the Promonotorio dos Principes de Avis looking onshore to the east. We employed a “dip stick’ coring strategy to recover a suite of down-core records at various water depths. Most cores penetrated to the last glacial period providing a unique opportunity to reconstruct hydrographic conditions across the last deglaciation from ~600 to 4600 m of water.

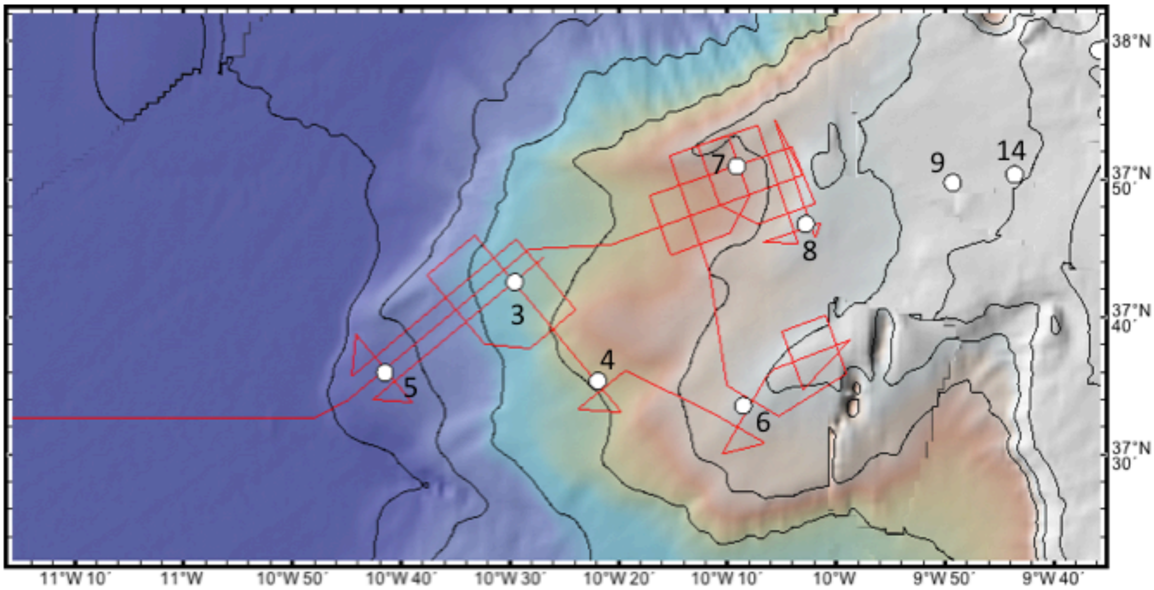


Figure 4. Ship's track during acquisition of seismic data. 755 line kilometres of seismic reflection profiles were acquired. Filled circles indicate position of station locations. Cores were recovered at six of the crossing seismic lines. It was not possible to survey east of approximately 10°W owing to the lack of a suitable chase vessel in the shipping management area.

Table 1. Station locations and water depths.

In order of occupation				In order of depth			
Stations	**Lat, N**	**Long, W**	**depth (m)**	**Stations**	**Lat, N**	**Long, W**	**depth (m)**
JC89-01	41° 00.00'	09° 28.50'	1299	JC89-15	37° 49.38'	09° 11.00'	405
JC89-02	41° 00.18'	09° 44.87'	2512	JC89-11	37° 51.51'	09° 20.15'	628
JC89-03*	37° 42.34'	10° 29.52'	3729	JC89-10	37° 50.50'	09° 30.65'	1127
JC89-04	37° 35.15'	10° 21.89'	3495	JC89-01	41° 00.00'	09° 28.50'	1299
JC89-05	37° 36.26'	10° 41.51'	4672	JC89-13	37° 56.12'	09° 35.10'	1448
JC89-06	37° 33.68'	10° 08.53'	2645	JC89-12	37° 58.35'	09° 35.91'	1611
JC89-07	37° 50.91'	10° 09.16'	3100	JC89-14	37° 50.16'	09° 43.61'	2062
JC89-08	37° 46.90'	10° 02.80'	2619	JC89-09	37° 49.83'	09° 49.30'	2323
JC89-09	37° 49.83'	09° 49.30'	2323	JC89-02	41° 00.18'	09° 44.87'	2512
JC89-10	37° 50.50'	09° 30.65'	1127	JC89-08	37° 46.90'	10° 02.80'	2619
JC89-11*	37° 51.51'	09° 20.15'	628	JC89-06	37° 33.68'	10° 08.53'	2645
JC89-12	37° 58.35'	09° 35.91'	1611	JC89-07	37° 50.91'	10° 09.16'	3100
JC89-13	37° 56.12'	09° 35.10'	1448	JC89-04	37° 35.15'	10° 21.89'	3495
JC89-14	37° 50.16'	09° 43.61'	2062	JC89-03	37° 42.34'	10° 29.52'	3729
JC89-15	37° 49.38'	09° 11.00'	405	JC89-05	37° 36.26'	10° 41.51'	4672

* = occupied twice

4.1.4 Water column sampling/measurement

Thirteen CTD casts were made using a trace metal free system to characterize the physical and chemical properties of water masses on the Iberian Margin. The data will be used to both interpret the water-column MCS profiles and for groundtruthing palaeoceanographic proxies in surface sediment. Water was collected at 13 stations using 10 litre Niskin bottles, totaling 246 bottles from which subsamples were taken for isotopic and elemental analysis.

Stand-Alone-Pumps (SAPs) were deployed at a total of 6 stations. The depths of the pumps were tailored to target the chlorophyll maximum, mid water particulate maximum(s) and bottom nephloid layers.

5. Diary cruise narrative

A note on station and core nomenclature. Station locations were numbered sequentially JC089-01 through JC089-015 (Table 2). The IODP proposal identified proposed site locations using the designation SHACK. Cores are numbered sequentially by type with the 4-letter campaign designator SHAK- followed by the station number, which is equivalent to the JC089 station number but differs from the IODP SHACK designation.

Table 2. Nomenclature for JC089 station names and the equivalent designation used previously in planning stages and in the IODP proposal.

Stations	Cores/CTD	IODP Proposal reference
JC089-1	SHAK1	(Morena-A)
JC089-2	SHAK2	(Morena-B)
JC089-3	SHAK3	(SHACK-6)
JC089-4	SHAK4	(SHACK-5)
JC089-5	SHAK5	(SHACK-7)
JC089-6	SHAK6	(SHACK-4)
JC089-7	SHAK7	(SHACK-1)
JC089-8	SHAK8	(SHACK-3)
JC089-9	SHAK9	(SHACK-2)
JC089-10	SHAK10	(MD95-2041)
JC089-11	SHAK11	
JC089-12	SHAK12	
JC089-13	SHAK13	
JC089-14	SHAK14	
JC089-15	SHAK15	

5.1 Precruise planning

JC089 required extensive pre-planning because of the multiple operations required to meet cruise objectives, including: 1.) geophysics; 2.) sediment coring; 3.) pore water geochemistry; 4.) water column sampling; and 5.) particle sampling using stand-alone pumps (SAPs). Because of the multi-disciplinary nature of the cruise objectives, the science party was organized with leaders for each sub-group: Geophysics (Nicky White), sediment coring (Nick McCave/Luke Skinner), geochemistry (Harry Elderfield/ Mervyn Greaves), and water column sampling and analysis (Alex Thomas). This organization was established early planning during the planning process as reflected by representation at the NMF precruise meeting in Southampton. The PS (Hodell) provided the interface among groups and oversight to ensure that the overall cruise objectives were met. This structure proved effective and was instrumental to the success of the expedition.

An initial planning meeting for scientists participating in JC089 was held on 05-02-2013 in Cambridge (Zurich and Lisbon participated via Skype). Hodell, McCave, and White attended the pre-cruise meeting with NMF in Southampton on 27-02-2013. Hodell, Greaves, and Elderfield met with Rachel Mills and Will Homoky in Southampton on 14-05-2014 to discuss the pore water geochemistry program. Hodell met with Tim Eglinton in Zurich on two occasions to discuss the SAP operations and sampling plans. Because of the considerable amount of administrative paperwork, John Nicolson was employed to complete all Risk and COSHH Assessments and compile shipping lists of all scientific supplies and equipment.

JC089 occurred in Portuguese waters and application for diplomatic clearance was submitted on 21-12-2012. The cruise involved a partnership with our colleagues at the Instituto Português do Mar e da Atmosfera (IPMA) in Lisbon, Portugal. IPMA has provided geophysical data and expertise to support the IODP proposal. The proposed sites were chosen at a Magellan workshop organized by Fatima Abrantes and David Hodell and held in Lisbon on 09-10 November, 2009. Three Portuguese scientists sailed on JC089 including Dr. Gabriella Carrera, Catarina Cavaleiro, and Celia Santos from IPMA.

5.2 Mobilisation - Southampton

Julian Day (JD) 206 (25/07/13)

Mobilisation of scientific equipment and supplies from Cambridge to Southampton. Hodell, Crowhurst, and Nicholson drove two large vans loaded with equipment and supplies, arriving in Southampton at 1730 (local time). It was too late to load equipment and supplies onto the ship, so vehicles were parked on dock awaiting unloading the next day. First night spent aboard ship.

JD 207 (26/07/13)

Unloaded vans and stowed equipment and supplies in ship laboratories. Informed that gas cylinders of N_2 had not been loaded onto ship. Order was placed with BOC for delivery the next day. The port time in Southampton and transit to Vigo was used to organize the equipment and supplies and set up the laboratories and methods to be employed during the cruise. Organizational meetings were held to plan geophysical aspects of the cruise.

At 15:00, the Captain of the vessel provided the ship safety presentation and orientation to the scientific party and technical personnel newly joining the ship.

Note that daily briefing meetings were held by the Captain at 08:30 on most days to review progress and outlook of the cruise. A 24-hour plan for science operations was posted by the PS daily when appropriate.

13 scientists and 6 technicians joined the cruise in Southampton for the transit to Vigo.

1. David	Hodell
2. Nick	McCave
3. John	Nicolson
4. Simon	Crowhurst
5. Harry	Elderfield
6. Mervyn	Greaves
7. Duygu	Sevilgen
8. Alex	Thomas
9. Nicky	White
10. Charly	Schoonman
11. Matt	Falder
12. Julia	Gottschalk
13. Anna-Lena	Grauel

Technicians:

1. Yvo	Witte
2. John	Wynar
3. Neil	Sloan
4. Jon	Seddon
5. Tom	Roberts
6. Ian	Murdoch

JD 208 (27/07/13)

Departure delayed until 1300 owing to leaks in seawater cooling pipework on starboard side. Engineers are working on the problem.

Informed that Alatas crane on starboard side is not working due to a hydraulic ram broken during testing. This crane is essential for all coring activities. Alatas to manufacture a new hydraulic ram and ship to Vigo for installation.

N_2 was never delivered by BOC but we rounded up enough bottles at NOC to supply the cruise.

Informed that departure delayed until 1000 on 28/07/13 due to cooling pipework problem on starboard side.

JD 209 (28/07/13)

Seismic acquisition planning team met at 9:00 to discuss survey location. Discussions led by Nicky White, David Hodell, Nick McCave, Matthew Falder and Charlotte Schoonman. The location of each of the proposed SHACK sites 1–7 was examined in the light of newly accessible TGS-Nopec survey which has lines oriented NW-SE and SW-NE. SHACK 7 on PD-00-530/530A was adjusted. SHACK 6, currently

in 3753 m water depth was moved to west to avoid unconformity on a compressional structure. On PD-00-525/525A, the best location is at shotpoint 500 instead of sp 1000 in water depth of 3975 m. Shifted primary site to sp 1045 which avoids small faults. Secondary site at sp 500. SHACK 5A on PD-00-527/527A was left on this line because alternative line BS-10 is poor quality. SHACK 4A located on BS-09 and on Steam-9407 has already been drilled to 150 m during IODP Expedition 330 (Site U1385). We kept this site but shifted it a little from sp 4500 to sp 5080. We added several more possibilities upslope of Steam-9407 at 7066 m and 6967 m. Site 3A is located just off PD-00-518, near lines BS-08 and 6165. The IODP panel did not favour this site because BS-08 is too low resolution. Two new crossing lines are required. We moved location along PD-00-518 from sp 3780 to sp 3880 to southeast. SHACK 2A is currently located in a region where there is evidence for channelization. Examining PD-00-616/615A/615B suggests that this site should be shifted left away from these channels 195 shotpoints (i.e. 2430 m) to southeast. Finally, SHACK 1A is due north of the last one near Steam-9414 and IAM GB-03 which are poor quality old lines. It needs to be located away from any mass transport deposits. Closest TGS-Nopec line is PD-00-518 which shows that this location is a difficult one. We have moved the site to the right to avoid structure. We compiled a list of extra TGS-Nopec lines which would be helpful to examine: (a) SHACK 7A & 6A: 523 NW end at sp 1000, 525 (yes), 527 NW end at sp 2000, 618; (b) SHACK 5A: sufficient lines; (c) SHACK 4A: 523 sps 3000–5000, 525 SE end with intersections at sp 4000, 616 at sps 5000–6000; (d) SHACK 3A: 519 NW end starting sp 01; (e) Site 2A: 515 (yes), 516 JC089 Seismic Survey 4
NW end at sp 1, 616 at sps 7000–9000, 615 at sps 8000–9000; (f) Site 1A: 518 (yes), 617 at sps 1400–1600.

The outcome of this meeting was a geo-referenced plot produced using Quantum-GIS that confirms optimal positions for crossing seismic lines to be acquired.

- Site SHACK 7: 37.5674^{o} N, -10.6312 ^{o} W
- Site SHACK 6A: 37.7084 ^{o} N, -10.6312^{o} W
- Site SHACK 6B: 37.7256^{o} N, -10.5337 ^{o} W
- Site SHACK 5: 37.5707 ^{o} N, -10.3727 ^{o} W
- Site SHACK 4A: 37.5715 ^{o} N, -10.1262 ^{o} W
- Site SHACK 4B: 37.6126 ^{o} N, -10.0666 ^{o} W
- Site SHACK 3: 37.7880 ^{o} N, -10.0039 ^{o} W
- Site SHACK 2: 37.8296 ^{o} N, -9.8228 ^{o} W
- Site SHACK 1A: 37.8517 ^{o} N, -10.1522 ^{o} W

At each site location, we plan to acquire multiple crossing points with multiple turns. We anticipate a turning rate whilst towing a 3 km long streamer of ~2^{o}/minute. Total line length between sites = 20 + 20 + 25 + 30 + 15 + 20 = 130km.

Departed Southampton at 1000 in good weather, wind 20 knot. Muster/emergency drill conducted at 1615.

5.3 Transit to Vigo, Spain

JD 210 (29/07/13)

Weather deteriorated to force 5–6 during night as we approached Bay of Biscay. Good bright morning with clouds. Improving throughout the day. Detailed examination of legacy seismic surveys and additional acquisition planning throughout the day.

Scientists are continuing to unpack and install equipment and supplies into ship laboratories. Continued to transit towards Vigo.

Informed that Alice Milner is unable to sail for personal reasons. Jenny Roberts will replace Alice in Vigo but needs to get ENG1 as NMF bureaucracy will not accept comprehensive medical completed for recent cruise aboard the *Polarstern*.

Ships clock advanced 1 hour to read GMT+2

JD 211 (30/07/13)

Calmer conditions with a blue sky.

Informed that Alatas was machining replacement ram for the starboard crane. They are aiming to have it ready for transport from UK to Vigo by Friday 2nd August. Assuming arrival Vigo on Saturday and 24 hr commissioning and testing time, then approx 2.5 days will have been lost (1 in Southampton) on original program. The time implications for diversion to Lisbon is currently greater than waiting on Alatas to transport ram to Vigo. Situation to be monitored continuously.

Safety committee meeting at 10:30. CTD cable needs to be streamed at a deep site. Inform engineers if gray water disposal (usually 9-11pm) or incinerator are to be delayed owing to CTD or stand-alone pumping.

Meeting to finalize seismic survey at 9:00.
(a) Sites 7& 6: 6 x 20 km = 14.4 hours; 4 x 35 km = 16.8 hrs; tight turns 4 x 90 mins = 6 hrs; fat turns 5 x x 2 x 90 mins = 15 hrs. TOTAL = 52.2 hrs.
(b) Site 5: 3 x 20 km = 7.2 hrs; 3 x 90 mins = 4.5 hrs. TOTAL = 11.7 hrs.
Site 4: 30 + (4 x 10) km = 70 km = 8.4 hrs; 90 mins +(4 x 90) + (4 x 90) = 9 x 90 =13.5 hrs. TOTAL = 21.9 hrs.
(c) Sites 1, 2 & 3: 20 km +(4 x10) km = 60 km = 7.2 hrs; 6 x 90 mins = 9 hrs; TOTAL = 48.6 hrs. Grand Total = 134.4 hrs = 5.6 days @ 4 kts. 50 km of transit lines = 6 hrs. 5.85 days JC089 Seismic Survey 5 or if turns take twice as long 8.3 days. This total suggests that we can afford weather downtime of 2 days.

Meeting at 10:00 to discuss the Environmental Impact Assessment (EIA) with accredited Marine Mammal Observers. John Nicholson (room 165), Julia Gottschalk (room 154), and Anna-Lena Graul (room 155). We discussed the general MMO plan and the details of the EIA. MMO log sheets are being finalized and are based upon JNCC guidelines.

Watches organized for geophysical group and MMOs. During seismic and coring operations, we will have 4 hours on, 8 hours off times two.

Approaching Vigo in calmer conditions with slight swell. Clear skies which clouded over by 22:00.

5.4 Mobilisation - Vigo

JD 212 (31/07/13)

Arrived Vigo at 0700. Overcast. Gravity base station measurements carried out on side of quay opposite ship's gravimeter. Gravity base station is located on separate quay (reference 014.07). Note that the written instructions and the diagram for the exact position of base station differ in detail.

Clearing skies. Logistics meeting with the Master. During seismic operations, we should be able to turn at 4–7 ^{o}/minute. Meeting with chase boat operators at 9:00. Present were Captain of Mytilus (Luis), Captain of Gamboa (Rafael Garcia) who acted as interpreter, and the two CSIC technicians (Ezekial and Minerva). The *Mytilus* has been chartered to accompany the RSS *James Cook* during seismic operations, especially within busy shipping lanes. Security messages from the ship will be relayed on VHS channel 72. We will meet again 4 days prior to departure from Vigo. Their transit speed is 8–9 kts. We will double up on bridge for conning operations. We will also advise Portuguese authorities that we are using a chase boat. Importance of having English speaker on board the *Mytilus*. At the end of seismic operations, the two Spanish technicians will be transferred to chase boat.

The co-ordinates of the shipping management area:
38^{o}N, -10^{o} 10' W; 37^{o} 31.3' N, -10^{o} W; 37^{o}0.8' N, -9^{o} 49' W.

Second meeting with the Master. Weather conditions in several days' time expected to deteriorate. Strong northerly winds are predicted for Wednesday/Thursday next week with 25+ kt winds and 2–3 m swell. Discussion about the shutdown procedures to be implemented during marine mammal observations. Meeting with Portuguese scientists to discuss changes to orientation of the distal part of seismic survey so that it is parallel to the strike of compressional structures.

JD 213 (01/08/13)

Hydraulic ram for Alatas crane is due to arrive on Friday, 02 August. Estimated one day to fit and test.
Informed that Chief Engineer has taken ill and needs to be replaced. Replacement to arrive Sunday, 04 August.
Scientists continue to unpack instruments and supplies, and ready laboratories for start of cruise.

JD 214 (02/08/13)

Scientific meeting at 14:00 with Dr Gabriela Carrara to alter seismic lines through sites SHACK 5–7. It is better if north-south lines are acquired where possible since prevailing wind and current are expected from north during August. We also need to consider location of Vessel Management Zone which will have high density of ship traffic. Clarification sought on NERC/NMF guidelines for MMOs and possible shutdown of seismic operations.

General scientific meeting to discuss cruise plan at 16:00 in conference room led by David Hodell. We have five sub-groups of scientists on board: i. geophysics, ii. sediment coring, iii. pore water geochemistry, iv. water column sampling, and v. stand-alone pumps (SAPs).

Sub-group meetings planned for 8:15 on Saturday (03/08/13).

Hodell emphasized the importance of safety and introduced contact people for safety issues: John Nicholson (Tel: 165, Cabin number 9); chemical safety: Mervyn Greaves (Tel: 148, Cabin number 16); PI: David Hodell (Tel: 247, Cabin number 4).

9 scientists and 2 technicians joined the cruise in Vigo for a total science crew of 22 scientists and 8 technicians:

Luke	Skinner
Natalia	Vazquez Riveiros
Jenny	Roberts
Maria	de la Fuente
Catarina	Cavaleiro
Clay	Magill
Daniel	Montlucon
Celia	Santos
Gabriela	Carrara

2 CSIC technicians

Ezequiel	Gonzalez
Minerva	Alegre

JD 215 (03/08/13)

Geophysics meeting at 8:15. Discussed calibration of swath bathymetry which requires deployment of SVP @ 60 metres/minute (~4 hours). Meeting with the Master to discuss chase boat issues. We will spend two days on way out of Vigo at the two Morena sites where boxcores and multi-cores will be taken. During transit between sites, the guns will be tested. ETA at Morena-1 is 5:00 on Monday and it is 30 nm between sites. Plan to set sail from Vigo at 20:00 on Sunday. The gun testing is a mechanical and synchronization one. Later on, we will have to ballast the streamer which is a slow operation. Seismic meeting reconvened to discuss deployment of SVP by mounting it on the CTD rosette. Deploy an XBT at the same site for calibration purposes. During seismic operations, we will also use the ADCP, sub-bottom profiler and fish-finder. Planned Start of Line for seismic survey is at 37^{o} 32.74^{o} N, −11 ^{o} 16.47’ W which is 7 hours away at 4 kts. Discussion of Plan B for SHACK 2A which sits within the Vessel Management Zone. This plan will focus on acquiring north-south lines in direction of vessels with minimal crossing lines.

Subgroups met to discuss procedures specific to each group including sampling protocols for water and cores. Logsheets will be created to track all operations and sampling activities. Once completed, these forms will be scanned by John Nicolson and pdfs created. These forms will constitute the permanent record of JC089 science operations (see Appendices).

Alatas crane's hydraulic ram arrived (driven from UK) and installed. Load testing to occur tomorrow.

5.5 Start of JC089 Science Operation

JD 216 (04/08/13)

Bright and sunny day with a cool start. Repeat gravity base station measurements quayside and at base station 014.07.

Evening departure (2000) from Vigo under calm conditions.

Discussion of watches for coring/seismic activities:

Marine Mammal Observers: John Nicolson, Julia Gottschalk, and Anna-Lena Grauel will be doing 24-hour MMO watches (3 x 8hr shifts) on the bridge during seismic activities.

12-4 shift (12am-4pm; 12pm-4am) Simon Crowhurst, John Nicolson, Nicky White, Jenny Roberts

4-8 shift (4pm-8pm; 4am-8am) Natalia Vázquez Riveiros, Luke Skinner, Gabriela Carrara, Matt Falder, Celia Santos

8-12 (8pm-12pm; 8am-12pm) Charly Schoonman, Julia Gottschalk, Daniel Montlucon, Clay Magill

Other groups:

CTD/Water sampling: Alex Thomas, Catarina Cavaleiro (watches as needed during CTD operations)

Chemistry: Mervyn , Harry, Duygu, Anna-Lena, Maria (watches as needed during pore water extraction of MegaCores)

Stand Alone Pumps (SAPs): Daniel Montlucon, Clay Magill

Nick McCave and David Hodell will share responsibilities for overseeing coring operations and are to be awakened whenever cores are taken.

The Alatas crane passed load test and is fully functional.

JD 217 (05/08/13)

The first two stations (Morena 1&2) will serve as a shakedown exercise for coring operations. These are the sites of two offshore long-term moorings deployed by the MORENA (Multidisciplinary Oceanographic Research in the Eastern Boundary of the

North Atlantic) project.

Arrived at Station JC089-1 (Morena 1, 41°N, 9° 28.5'W, 1299 m). 3.5 kHz was run E-W across site before turning back to station. Bottom looked hard. Two failed attempts at box core. The first did not trigger as it got snagged on a broken wire. The second did not penetrate sufficiently to knock the trigger arm up. On third attempt, the box core (1B) was put in at 40 m min^{-1} and successfully triggered but only a 9-cm scrape of sediment was obtained on one side of the box core. Concluded the bottom is likely too hard.

Gun testing was carried out in calm conditions with a minor swell. 12:30 guns in water. MMOs on station since 12:00 and we stayed on hold for MMOs until 13:00 in accordance with guidelines. Gun firing started just after 13:00 with guns at 5 m depth. Recording shack can see single gun firing to start with. Second gun added but it was misfiring. Once fixed by 14:00, both guns firing every 20 seconds. Muster/lifeboat drill at 16:15. We ended gun test at 17:00. Plan to launch an SVP attached to CTD wire. Once it came back up, we deployed the first disposable hydrographic probe, an XBT. CTD was deployed at 18:15 on starboard side. Still coming back up at 20:00.

XBT-1 finished at 20:50 and was successful to 2200 m. Mediterranean Overflow Water (MOW) clearly visible. Jon Seddon proceeded to calibrate the swath bathymetry system whilst steaming ahead at 2 kts.

Station JC089-2. (Morena 2)
Transit to Station JC089-2 (Morena-2). Conducted a CTD cast (CTD 01) in 2506 m of water. Water samples taken at 5, 20, 45, 60, 100, 250, 500, 800, 1000, 1175, 1500, 2000, 2405, and 2505 m.

JD218 (06/08/13)

Station JC089-02. (Morena 2) (41° 0.17N, 9° 44.87W, 2518 m)

On site for coring at Morena-2. Identified optimal location on 2.5–7 kHz pinger. 7:00 box corer deployed in 2532 m. Corer has probably overpenetrated from the tension values recorded. At 8:00, box corer SHAK-02-2B recovered with 33 cm of sandy mud. Sampling carried out and operation complete by 9:00. Multicore -01M deployed at 8:30 and expected up at 10:30. When recovered, 5/6 corers were full (1/4 sediment, 3/4 water on average). Kasten core SHAK-02-1K deployed at 11:10. Recovered 1.48 m of sandy mud at 13:30 and then processed.

CSIC Barcelona have informed us that we do not require a chase boat to guard the streamer provided we are not within shipping lanes. This is a welcomed development.

Underway in afternoon towards Site 6. Calm seas with slight swell.

JD219 (07/08/13)

7:00 start with slight swell. Good conditions. Magnetometer deployed for testing from port stern using boom while steaming ahead at 4 kts. Appears to be recording ok. At 37°

42.652' N −10° 29.544' W and acquiring swath bathymetry to assess coring possibilities. Magnetometer still ok apart from time stamp which Jon Seddon will fix. Strong current here. Swath bathymetry looks good and on the pinger we can see nice layered sediments down to about 1 km depth. Turned back towards Site SHACK 6B and on station at 8:30. Good conditions with slight swell.

8:30 meeting with the Master and with Neil Sloan. We will include a CTD cast here. Clarification regarded requirement of chase boat expected from CSIC and from NMF later today. Not much ship traffic out here. Tomorrow we are expecting a strong northerly wind. Series of cores to be taken here and then a CTD. The chase boat, *Mytilus*, will take 38 hours to reach us, which means 14:00 tomorrow afternoon. Streamer ballasting and deployment will take up to 8 hours @ 3.5 kts. So we will allow 6–12 hours for deployment. Discussed ship's trajectory during streamer deployment to ensure timely arrival at Start of Line. Seismic survey still projected to take about 3 days to complete.

Rendezvous point with *Mytilus* will be 37° 32.7431'N; 11° 16.465'W. While waiting on rendezvous with *Mytilus*, we will conduct coring operations at Shack 6C as time permits.

Station JC089-3 (Proposal SHACK-06)
Shack 6C was located on a submarine cable so we changed the position to 6B (37° 42.54'; 10° 29.56'W, 3735 m) to avoid cable.

A box core (SHAK-03-3B) was deployed to 3770 m at 06:30 and obtained between 33 and 37 cm with sloping surface. Over half of the surface was covered with debris (kicked up by corer?) which was scraped clean before subsampling. Oxidized surface layer at top 10-cm of box core.

Piston Core (SHAK-03-01P) was deployed at 10:34 with an 18 m barrel consisting of 3 sections. Possible piston jamming problems since penetration was rather better at 14.7 m. Only 5.14 m core was recovered by the piston core and trigger core was 1.45 m. The core was later split, described, and sampled at 1-cm intervals.

At 13:38, the Megacore was deployed (SHAK-03-02M) and 8 cores were recovered with sediment. On recovery, the shackle was caught on the mechanism stopping it going up and skewing the Mulicorer, so tubes with instrument suspended in the air.

We ran out of time so kasten core was not taken at this time. The intent is to return to JC089-03 later in the cruise to take a kasten core at this station.

Ship was repositioned to 37 42.54°N, 10° 27.55'W to take CTD. At 17:50, the CTD (SHAK-03-02CTD) was deployed with an SVP to a depth of 3732 m. All 24 bottles fired.

At 22:30, ship was repositioned to 37 41.12°N, 10° 27.78'W for initial deployment of stand alone pumps.

JD220 (08/08/13)

SAPs (JC-089-03 SAP-1) carried out overnight by Daniel and Clayton. Finished by 7:15 in the morning. Transit to vicinity of deployment of seismic gear (37° 2.4'N, 11° 25.1'W)

Weather forecast suggests brisk winds of up to 30 kts for next 48 hours. 8:30 meeting with the Master. Currently 25 kt winds with 3 m swell. Expected for at least next 24 hours. *Mytilus* expected at 13:30 in difficult conditions for them.

We will use a 20 second firing interval for seismic operations which is plenty of time for compressors. The Power Management System problems encountered on earlier cruises have now been fixed. We are using Avalon and not Big Shot to synchronize firing and recording systems.

12:30 discussion about timing of streamer deployment in these deteriorating conditions. Meeting on bridge with Spanish technicians. Wind speed is 21 kts. Continued discussion about requirement for chase boat. Technicians speak to Juan-Jo Danobeitia at CSIC/UTM for clarification. We do not anticipate significant ship traffic for first 3 days. Main problem is that Jose Luis Alonso (seismic department, Barcelona) and Jordi Sorribas (VP of UTM) may require chase boat presence at all times. Later, Master receives email clarification from Juan-Jo Danobeitia which states that chase boat is not a requirement until we reach the shipping corridor.

At 14:45, the tailbuoy is finally in the water commencing streamer deployment operations. Wind speed up to 25 kts with a growing 2–3 m swell. Workable conditions but only just. Heading NNE. Decided to continue streamer deployment.

17:00 and *Mytilus* is off the end of the streamer which is about half way out. Some problems with streamer connection deemed minor. Reattaching fifth bird at 17:00. Sixth bird attached at 17:30. Streamer @ 2 km. Minor problem with bridge not seeing display for tailbuoy. At 18:30, wind has dropped a fraction to 23 kts.

18:40 rest of streamer deployed and we should start shooting in about 1 hour.

MMO deployed on bridge as per guidelines. Guns deployed and ready for firing at 20:00. Too much swell to risk deploying magnetometer tonight. Seismic acquisition geometry finalized. Guns are in 5 m of water and towed 25 m aft of stern. Streamer at 9 m water depth. Speed of 4 kts. 20 seconds firing and 14 seconds recording. Jon Seddon talks the watch keepers through the state-of-health logging which will be carried out every half an hour. 20:40 @ 37° 24.151' N 11° 18.941' W in 5514 m. Guns started and immediate compressor problems. Problem fixed quickly and guns restarted at 20:53 (18:53 GMT).

At 11:30, we turned onto SOL but the gun array is being pushed rather badly beneath the streamer due to crabbing of ship in these weather conditions. Decision to take in guns at 11:40. Difficult conditions beam on as we attempted to turn onto the line. Guns in at 11:50. Streamer is safe at 9 m depth but we may need to deepen it if conditions get any worse. Resume northerly course for now. Forecast should slowly improve and there may be a Saturday/Sunday window for acquisition. Next week looks bad. Moderate gale all night.

JD221 (09/08/13)

The white caps have gone but there is still a good swell at 7:30 with wind at 27 kts. Meeting at 8:30. Plan to deploy guns this evening 32 nm north. Waiting for it to ease up before we turn using azimuthal thrusters. Using WGS84 for navigation. Meet again at noon to review. We started a starboard turn at 10:00 to come down towards Site SHACK 6. Developed a new acquisition plan in the light of poor weather conditions and adverse current direction which precludes portside turns. 10:45 now running EW on this starboard turn which is slow work. 4–5 kts. 13:00 still Force 6 and 25 kt wind. 13:20 @ 37^{o} 6.603' N, −10^{o} 52.736' W. Bridge request new waypoints for revised plan. Delivered a Plan B in detail at 13:30. At 17:00, 14 nm from lead into start of survey. Conditions are a bit better with 14 kt wind coming down all the time. Rather slow @ 3.5 kts so touched up speed to 4.5 kts. 19:10 guns prepared for deployment ahead of waypoint @ 37^{o} 53.723' N, −10^{o} 21.505' W. 19:30 down to 3.5 kts to put guns out. Soft start for guns at 20:00 in compliance with JNCC guidelines. Unfortunately, we have no shot gather or near trace stack display in main lab and so quality control will be difficult to monitor. Operating blind. We need to carry out a test record at 21:20 as we run onto line. Run-in @ 37^{o} 46.366' N −10^{o} 24.018' W. Gun signature for gun1 is OK but problems with gun 2. It has small amplitude and a bad peak to bubble ratio. Might be a hydrophone issue. 21:50 we are now 4 minute from SOL. Problem with set-up of GI guns in the shack. Neil Sloan called RTS in Texas for guidance about way in which guns are set up. We are going to have to turn shortly. Guns rewired in the seismic shack in the nick of time! Problem was incorrect wiring by technicians.

22:30 SOL. XBT deployed a few minutes after SOL on low fold. Session at 23:00 with Matthew Falder who has designed a seismic processing flow which can be used in almost real time to monitor data quality. Not as good as shot and near trace displays but it is the best we can come up with. SEGD files copied to his laptop and shots can be processed and displayed using simple gain and filter. Brute stack construction to examine chunks of data.

JD222 (10/08/13)

2:05 continue shooting. Temporary problem with possible loose connection for XBT launcher on aft port so gap in deployment after the first two. Swell has built and wind speed is now 20–25 kts. Shot gathers are noisier but brute stacks look ok. Continue to process chunks of data with streamlined SU sequence. 3:00 just starting turn onto Line 2. Some noisy traces: bird problems? Continue to copy streaming data onto Cambridge Terrabyte drive for QC processing. Problem with gun synchronization became apparent. 5 ms gap between guns grows periodically to 20 ms and then corrects back to 5 ms. Very unsatisfactory. Potential wiring issue again? OK when turn second gun off. 9:45 Neil Sloan investigates in seismic shack again. 10:00 rewired guns are now good and 'double seabed' has disappeared. Shot points look good. 11:30 wind is at 17 kts. 14:10 successful run along Line 2 with deployment of a series of excellent XBTs. Start to turn onto Line

3. Update copying. Check that watch keepers understand the XBT recording drill. Make sure that files are saved and that position is correctly recorded (edf and rdf files).

JD223 (11/08/13)

01:00 good conditions turning onto Line 5. Some shots are missing when we stop/start a line since cease recording momentarily. Checked shot record 5300 at 3:45. Some bands of bird-related noise but otherwise good quality. Meeting at 8:30. Steam to Vigo at cruise end on 25th August. 3 hours to take in streamer. 12:15 compressor failure and simultaneous but unrelated failure of communication with tailbuoy. Former could be the old PMS problem we had on JC50. Neil Sloan looks into it. 15 minutes later, we have one compressor working again. Tail buoy is just visible from bridge but there is no GPS connection. We might need to recover streamer to check on integrity of connection. PMS issue resolved by overriding. One compressor working. Tailbuoy continues to be visible from bridge and can be seen with RADAR provided that the buoy is not directly astern in RADAR shadow. Thus we have visual control which can be logged by the MMO every 20 minutes, say. We can also calculate from bird compasses where the streamer is. A plot of line track and tailbuoy position up to now shows that tailbuoy precisely follows the ship track, occasionally coming a little inside on the turns. 13:45 continue recording. The Master agrees that we can continue without tailbuoy communication, which is not essential. Technicians are more reluctant but will check with CSIC/UTM.
Feather information not normally used in processing in any case. Compressors continue to perform well thanks to PMS bypass. We also instigate another single gun test. Back with two guns at 13:48 (about 20 shots worth of one gun). Need to carefully examine this series of shots. Definitely an issue still. Ringing in data disappears when we use one gun alone. Turned gun two off permanently. Meanwhile the tailbuoy issue has worsened. It could be a weakened mechanical link rather than just a broken antenna. Unfortunately, we carry no spare parts for streamer connection so if the tailbuoy connector is compromised we will be unable to continue shooting. 18:30 tailbuoy issue reaches a head. Last record before streamer recovery. Stopped guns at 18:35. Start taking streamer in at 19:00. Streamer on board at 18:39 GMT. Mechanical connection between streamer and tailbuoy is sound but there was electrical burnout in the GPS cable which caused the loss in communication. Some evidence for physical stretching. Streamer cannot be deployed again until 6:30 ship time due to hours of rest requirement.

Transit to JC089-04 (37° 34.78'N, 10° 21.48'W, 3482 m) as a contingency for coring operations while waiting to resume seismic operations. We had to move the site about 1000 yards to the NW because proposed site was near a submarine cable.

21:45 Deploy CTD rosette at JC089-04 (SHAK-04 CTD-03) to 3398 m.

So far, we have deployed 34 XBT/XCTDs of which 4 are XCTDs. We have 66 probes left and 25 crossing seismic positions. Remained on Dynamic Positioning for rest of night. Aim to start coring procedures at 7:00. Issue of being 200 m from a pipeline so will have to move an additional 800 m away.

JD224 (12/08/13)

8:30 meeting. Plan for multi, piston and kasten coring followed by SAPs. End of play yesterday concerned tailbuoy issue. Technicians to seek advice. Can we work around the electrical issues?

Mytilus is still on standby since it headed back to port during the spell of bad weather when we first started acquisition. Problems with compressors. Confusion over issue: is it a PMS issue or integrity of compressors? Water consumption up over last few days.

12:00 looks like streamer is still useable. Looking at electrical and mechanical coupling. Technicians are optimistic but Neil Sloan is less so.

At 08:07, the Megacore (SHAK-04-3M) was deployed to 3495 m. All 8 tubes recovered sediment.

At 12:22, Piston Core (SHAK-04-2P) was deployed and recovered 10.69 m which was cut into 8 sections. The piston core was later split and described. Working half was sampled at 1-cm increments and bagged.

Determined that streamer can be used. Need to remove GPS link to tailbuoy and ensure that the battery has enough power to keep the light on for the rest of the survey since electrical connection is broken. Mechanical link seems to be ok despite some concern about its looseness and a broken mechanical fuse. Spoke to Neil Sloan about the gun problems. Lack of synchronization between two guns an issue. He says that this is a CSIC issue rather than an NMF one but he will talk to RTS again. Otherwise, we will just use one gun. Plan to put streamer out in the morning and to come back into abandoned waypoint.

At 14:48, a Kasten core (SHAK-04-2K) was deployed and recovered 3.25 m of mud plus core catcher. It took approximately 5 hours to process and sample the kasten core.

No box core was taken at this station.

20:30 Reposition ship to 37^{o} 33.2’N, 10^{o} 21.5’W to begin SAP operation. Daniel and Clay deployed SAPs (JC-089-04 SAP-2) two miles up current (2nm due south) from coring location for SHAK-04.

We plan to resume seismic acquisition at 7:00 in morning following 5 hours of SAPs. We are now about 3 hours steaming from SOL.

JD225 (13/08/13)

8:30 deploying streamer. Technicians are unhappy with weather conditions but in fact conditions are rapidly improving. Wind speed 20 kts and dropping. Anenometer is currently broken and showing incorrect wind speed. Continue to deploy. Streamer fully deployed by 10:30. Gun testing at 10:50. Conditions are OK. 1 m swell and 20 kt wind. Better than before: no white caps now. 1 hour to go to the lead-in. Coming onto line

@12:45. Looks good but problem with second gun still. Perhaps the solenoid is sticking? So perhaps mechanical as opposed to Bigshot timing issues. 14:15 all OK. One gun only. Coming up on SOL. 16:00 now on a 070 heading and crabbing but guns and streamer are maintaining separation. 18:15 Neil Sloan thinks that solenoids are gone in gun two and so plan to bring in guns to change solenoids on a turn. Requires downtime of at least one hour. Guns in @ 18:40. By 19:05, guns are back in the water. The solenoids were fine so problem is probably a software issue. Shotpoint 1910, still messing around with gun testing of one and then two guns. 20:00 major problem in that single gun is now not firing correctly but has an increasing delay of seconds. Large and increasing time delay persists so decision made to shut down system and restart. System restarted @ 21:30 and now single gun firing OK. Coming onto line. SOL in 25 minutes. Decided to stick with just one gun.

JD226 (14/08/13)

00:00 all going well on single gun. Wind speed 20 kts and we are beam onto a 2–3 m swell which is producing significant roll but data quality good. Update copying. Change to Line 11 towards end of turn. 3:55 wind steadies to 18 kts Force 5. 8:30 meeting with the Master. Expect to wrap up seismic survey on Friday. We will then start coring program in earnest. Traffic-wise, everything looks ok and the few vessels have been responsive. Weather is calming down but will pick up again on Friday pm. Next two days are expected to be set fair. 12:00 good progress. 12:20 successful XBT. End of Line 13. 14:45 continuing OK
with good weather.

JD227 (15/08/13)

Conditions are good with 15 kt wind and swell of 1–2 m. A remaining inventory of 7 XCTDs and 28 XBTs and discussion of plan of deployment. 2:00 finish deploying XCTD which was spiky so perhaps our speed was a bit high @ 4 kts. Started Line 18. Another XCTD deployed at 2:35. 9:00 post meeting when finishing time of seismic survey was discussed. Probably tomorrow morning. Conditions continue to improve. Wind speed of 10 kts. Little swell with some fog. Last few crossed lines being acquired now. Lines 20 and 21. 18:30 meeting about logistics post seismic surveying. Streamer in with about 8:00 start so all in by noon. SVP will be deployed when winch wire is streamed which will take 3 hours. Need to forgo seismic survey of Proposal Shack-02 owing to shipping lanes, which could also be a problem for IODP drilling (need to flag in proposal). We hope to acquire data from TGS which has good seismic coverage of the area.

JD228 (16/08/13)

00:05 Wind has picked up to 15–20 kts. Air pressure is 1019 mbar. XBT data now show a large and persistent overturn. Should be clearly visible on seismic data. Lines 23 and24. Examined shotgather 18300 which has minimal streamer/bird noise. Modest water reflections beneath direct arrival. 3:00 weather continues to deteriorate. Wind now 22 kts Force 6. Along this E-W line, the ship is crabbing which pushes streamer onto starboard side. As a result, the last run of 4–5 XBTs ended at shallow depths because the copper line hit the streamer. EOL and end of survey at 7:15 on bona fide oceanic crust.

Station JC089-05 (Proposal SHACK 7 – deep water site):

After the end of the seismic survey, we streamed the CTD cable in deep water (5 km) before transiting to the deep-water site JC089-05 (37^o 36.26'N; 10^o 41.5'W, 4670) for coring operations. The deep-water site was chosen to coincide with crossing MCS. The piston core (SHAK-05-3P) was deployed under favorable weather conditions at 1700 and obtained 7.5 m of sediment. The Megacore (SHAK-05-4M) was deployed at 20:40. Seven tubes of sediment were recovered each containing ~10 cm with one failure (Tube C).

JD229 (17/08/13)

Station JC089-05 (Proposal SHACK 7 – deep water site)

SHAK-05-CTD5 was performed at 0130 and water samples obtained at 5, 20, 30, 55, 250, 600, 1000, 1300, 2000, 2500, 3000, 3700, 4000, 4551, and 4646 m. No SAPs were deployed at this station.

A Kasten core (SHAK-05-3K) was deployed to 4690 m at 05:45 and retrieved at 10:20 (~2.5 hours round trip). The winch motor overheated at 2000 m on the way up and the retrieval was halted. Retrieval was resumed after engineers fixed a cooling fan. SHAK-05-3K recovered 4.68 meters of mud, now with correct core catcher.

After recovery of the Kasten core, we transited to *Station JC089-06 (Proposal SHACK 4 – the "Shackleton site") at 37^o 33.67'N, 10^o 8.53'W.* This is the same location as Piston core MD01-2444 and close to Site U1385 (the "Shackleton site") drilled by IODP on Expedition 339. Because of existing piston and IODP cores at this location, we decided not to deploy the piston corer at this location and instead focused on recovering near surface sediment for calibration work using the mega- and kasten coring systems.

We began with a Megacore (SHAK-06-5M) to 2665 m at 14:30 which recovered 8 tubes, each with ~30 cm.

Box core SHAK-06-4B was deployed at 18:06 and recovered 47 cm. It was subsampled following standard procedures.

Two kasten cores were taken at this station: one for Cambridge (SHAK-06-4K) and one for ETH (SHAK-06-5K).

At 20:10, Kasten core SHAK-06-4K was deployed using a 6-m barrel. A total of 4.75 m was recovered.

22:50 Reposition ship to 37^o 33.4'N, 10^o 8.2'W for CTD (SHAK-06-CTD05)

JD230 (18/08/13)

Daniel and Clay deployed SAPs (JC-089-06 SAP-3) through the night with coring operations to begin at daylight.

At 06:55, Kasten core SHAK-06-5K was deployed for ETH consisting of a 4 m barrel. 3.44 m were recovered and the core was sampled by Daniel and Clay at 1-cm intervals over its entire length. A u-channel was taken for XRF analysis at Cambridge and paleomagnetic analysis at U. Florida.

Transit to 37^o 42.45'N, 10^o 29.55'W to recover the kasten core that we missed previously at Station JC089-03. We decided to retain the same station name as before (JC089-03) to avoid confusion, but note that the kasten number will be out of sequence for this station.

11:32 Kasten core (SHAK-03-6K) was deployed to 3685 m. 4.16 m of sediment was recovered and processed using standard protocol.

Transit to next *Station JC089-07 (Proposal SHACK 01B)* at 37^o 50.9'N 10^o 9.1'W.

17:30 A Megacore (SHAK-07-6M) was taken in 3135 m if water. All 8 tubes were successful with ~26 cm of mud.

21:04 A piston core (SHAK-07- 4P) was taken in 3081 m of water. The corer recovered 10.2 m of sediment and was cut into 8 sections.

JD231 (19/08/13)

00:31 The ship was repositioned to 37^o 50.8'N 10^o 9.3'W for a CTD cast (SHAK-07-06) in 3062 m of water.

SAPs (JC-089-07 SAP-4) were deployed overnight.

The ship was repositioned over the coring site in the morning to continue with coring operations. At 04:30, a box core SHAK-07-05B was taken in 3137 m

08:30 A 4.24-m long Kasten core (SHAK-07-07K) was obtained in 3132 m of water. Only one set of trays was taken because we depleted the supply of styrene trays. A D-tube was cut and used to subsample the kasten core in lieu of trays.

We transited to Station JC089-08 (Proposal SHACK 03) at 37^o 46.6'N, 10^o 02.2'W

11:57 A Megacore (SHAK-08-07M) was deployed in 2543 m of water. There was some concern about a potential nearby cable so the ship was moved using dynamic positioning to 37^o 46.9'N, 10^o 02.8'W with 1500 m of cable out. All eight tubes successfully recovered about 30 cm of mud.

16:00 A 9.2-m piston core (SHAK-08-05P) was recovered in 2590 m of water.

17:55 Box core (SHAK-08-06B) was deployed in 2646 m

Ship repositioned to 37° 47.7'N, 010° 2.79'W for CTD (SHAK-08-CTD-07) in 2580 m water depth.

JD232 (20/08/13)

SAPs deployed overnight (JC-089-08 SAP-4) and then repositioned over core site in the morning.

05:54 Kasten SHAK-08-08K was taken in 2640 m of water and recovered 4.15 m of sediment.

Transit to Station SHAK-09 (Proposal SHACK 02) at 37° 49.82'N; 9° 49.29'W, 2323 m.

10:50 Megacore SHAK-09 -08M was deployed in 2320 m, 7 cores recovered, 1 failure.

13:45 Piston core SHAK-09 -06P was taken in 2300 m of water, 9.02 m of sediment recovered.

15:36 Box core SHAK-09 -07B was deployed in 2327 m of water

18:32 Kasten SHAK-09 -09K taken in 2346 m of water, 5.02 m of sediment recovered.

Reposition ship to 37° 49.99'N, 9° 49.09'W for CTD and SAP deployment.

20:50 SHAK-09 -08CTD to 2308 m.

SAPs (JC-089-09 SAP-5) deployed overnight by Clay and Daniel.

JD233 (21/08/13)

Station JC089-10 (location of MD01-2041) at 37° 50.00'; 9° 30.65'W in 1127 m of water.

08:22 Box core SHAK-10-08B to 1144 m. 55 cm box full.
09:53 Megacore SHAK-10-09M to 1150 m. Two tubes failed, remaining 6 recovered about 40 to 50 cm

11:15 Kasten core SHAK-10 -10K to 1150 m. Recovered 4.18 m of mud.

15:30 Piston core SHAK-10 -07P to 1127 m. Recovered 8.08 m of sediment. Difficult to extrude from pipe owing to imploded liner.

16:02 SHAK-10 CTD-09C to 1100 m

19:20 SAP (JC-089-10 SAP-6) to 1114 m

22:00 With the recovery at cores at SHAK-10, we completed the pre-planned coring sites for the cruise. We decided to run a 3.5kHz- and swath survey to locate potential coring sites in intermediate water depths. Nick McCave provided the bridge with coordinates and surveying continued throughout the night. Several promising sites were identified and we used the remaining cruise time to core at these locations.

Coring and survey way-points

	Latitude		Longitude		
	Deg.	Min.	Deg.	Min.	
From MD2041	37	50.0	9	30.6	at 5 knots
	37	53.8	9	28.8	at 5 knots
	37	51.2	9	18.9	at 5 knots
	38	0.0	9	28.1	at 5 knots
	38	6.4	9	25.9	at 5 knots
	38	6.9	9	28.9	at 5 knots
	37	55.6	9	33.0	at 5 knots
	37	56.7	9	37.7	at 5 knots
	37	59.8	9	36.4	at 5 knots
	37	55.6	9	33.0	at 5 knots

On the basis of the survey coring stations will be selected

JD234 (22/08/13)

The CSIC techs were transferred to Launch "Cais Mar" for transport to mainland.

Station JC089-11 (37 º 51.51, 9º 20.16'W, 618 m)
11:46 Box core SHAK-11 -09B recovered about 30-32 cm of mud.
12:48 Megacore SHAK-11 -10M. Two tubes failed and the remaining 6 had between 14 and 24 cm.
14:10 Gravity core SHAK-11 -01G recovered 4.58 m of sediment.
We decided to substitute gravity for kasten cores owing to the long time required for processing kasten cores and the fact that we consumed all the trays for subsampling the kasten cores. Gravity core was subsequently split by McCave/Skinner and stored in D-tubes.

15:20 CTD-10C

Station JC089-12 (37º 59.36'; 9º 35.91'W, 1607 m)
18:17 Box core SHAK-12-10B
20:05 Megacore SHAK-12-11M. Two failed and the remaining 6 recovered between 35 and 41 cm.
22:10 Gravity core SHAK-12-02G recovered 5.35 m of sediment.
Gravity core was subsequently split by McCave/Skinner and placed in D-tubes.
23:38 SHAK-12-CTD-11C

JD235 (23/08/13)

Station JC089-13 (37º 56.15'N; 9º 35.10'W, 1440 m)
02:30 Box core JC-089-13-11B
05:00 Gravity core JC-089-13-03G recovered 5.19 m of mud.
Gravity core was subsequently split by McCave/Skinner and placed in D-tubes.
05:37 Megacore JC-089-13-12M 2 tubes failed and one only recovered 6.5 cm.
Remaining 5 recovered about 40 cm.
08:00 Piston JC-089-13-08P recovered 5.95 m of sediment.
10:03 CTD JC-089-13-12C

Station JC089-14 (37º 50.16'N, 9º43.61'W, 2063 m)
14:44 Box core -12B
16:55 Gravity core SHAK-14-04G recovered 5.13 m of mud.
Gravity core was split and placed in D-tubes.
18:49 Megacore SHAK-14-13M. About 40 cm in all eight tubes.
21:30 Piston core SHAK-14-9P recovered 9.28 m of sediment.
23:44 CTD SHAK-14-13C

JD236 (24/08/13)

3.5 kHz and swath run back to Station JC089-11 (37º 51.51'N, 9º 43.61'W, 575 m) to obtain piston core.

06:58 piston core SHAK-11-10P taken in 575 m of water. Recovered 1.93 m of sandy sediment.
09:00 Station SHAK-15 (37^o 49.38' N; 9^o 11.00'W, 405 m). The last core of the cruise was obtained at 08:27 and was a Grab sample (SHAK-15-1Gr) that obtained surface sediment in 405 m of water.

Weather was deteriorating (wind 30 knots with frequent gusts up to 40 knots) and captain informed us that there would be no further science involving overside equipment, deck secured for transit.

This marked the end of science operations for JC089 and we began our transit to Vigo.

The NERC Cruise Assessment Form completed by the Principal Scientis and a debriefing was held in the Library at 10:30hrs.

5.6 Transit to Vigo

JD237 (25/08/13)

Transit to Vigo, weather deteriorating (30-40 knots, max gust 51 knots)
Breaking down instrumentation and packing equipment and samples. All equipment and samples to be loaded in 20 ft refridgerated shipping container that will be shipped directly to Cambridge, unloaded, and then returned to NOC. Arrangements made to rent a 20 ft refrigerated container in Cambridge and transfer contents from NOC container to hired one.

JD238 (26/08/13)

Arrived Vigo at 16:30 and completed passage to berth at 18:05.

5.7 Demobilization Vigo

JD239 (27/08/13)

Demobilization began at 08:00.

JD240 (28/08/13)

Science party disembarked from vessel.

6. Station/activities log

Table 3. Station activities log.

Start Date	Start Time	End Date	End Time	Latitude	Longitude	Water depth	Wire out	Event Description All times Local time (GMT +1 to GMT +2))	Station name	Activity identifier	Comment
JC89-01	**Morena 1**										
05/08/2013	06:15	05/08/2013	10:56	41° 00.00'	09° 28.50'	1299	1328	Box core	JC89-01	SHAK-01-1B	after 2 failures, hard bottom.
JC89-02	**Morena 2**										
05/08/2013	17:34	05/08/2013	20:32	44° 00.17'	09° 44.88'	2506	2500	CTD	JC89-02	SHAK-02-1CTD	water samples @5,20,45,60,100,250,500,800,1000,1175,1500,2000,2405,2505 m.
06/08/2013	05:33	06/08/2013	07:40	41° 00.18'	09° 44.87'	2512	2537	Box core	JC89-02	SHAK-02-2B	
06/08/2013	07:40	06/08/2013	10:33	41° 00.18'	09° 44.87'	2512	2537	Megacore	JC89-02	SHAK-02-1M	recovery: 12, 11.5,10.5,0,10.1,0,17.9 cm
06/08/2013	10:33	06/08/2013	13:10	41° 00.17'	09° 44.87'	2514	2537	Kasten core	JC89-02	SHAK-02-1K	recovery: 1.48m, 4m barrel, wrong core catcher
JC89-03	**SHAK-03-3B**										
07/08/2013	08:29	07/08/2013	11:30	37° 42.54'	10° 29.56'	3731	3770	Box core	JC89-03	SHAK-03-3B	recovery: 33-37cm
07/08/2013	11:30	07/08/2013	15:20	37° 42.45'	10° 29.55'	3731	3770	Piston core	JC89-03	SHAK-03-1P	recovery: 5.14 m
07/08/2013	15:20	07/08/2013	19:00	37° 42.34'	10° 29.52'	3729	3770	Megacore	JC89-03	SHAK-03-2M	recovery: 22,26,26,27,13,13,26,27 cm
07/08/2013	19:50	07/08/2013	23:15	37° 42.54'	10° 29.56'	3740	3732	CTD	JC89-03	SHAK-03-2CTD	water samples @5,20,50,85,100,200,525,750,1000,1400,2000,2500,3000,3500,3632,3726.
07/08/2013	23:26	08/08/2013	07:05	37° 41.1'	10° 27.78'	3646		SAPs deployment	JC089-03	JC089-03-SAP1	pump depths @ 10, 65, 420, 1250, 2000, 3030, 3514 meters
JC089-04	**SHAK4**										
11/08/2013	23:35	12/08/2013	03:10	37° 34.79'	10° 21.79'	3464	3398	CTD	JC89-04	SHAK-04-3CTD	water samples @5,25,45,60,75,250,425,700,1000,1250,4650,2000,2500,3300,3378,3472.
12/08/2013	07:25	12/08/2013	11:02	37° 35.15'	10° 21.89'	3495	3505	Megacore	JC89-04	SHAK-04-3M	recovery: 28,29,31,31,20.5,17.5,32,29 cm
12/08/2013	11:28	12/08/2013	15:05	37° 35.15'	10° 21.89'	3477	3459	Piston core	JC89-04	SHAK-04-2P	recovery: 10.69 m
12/08/2013	16:44	12/08/2013	19:10	37° 35.15'	10° 21.90	3477	3470	Kasten core	JC89-04	SHAK-04-2K	recovery: 3.25m, 6m barrel, wrong core catcher
12/08/2013	20:30	13/08/2013	03:15	37° 28.08'	10° 11.76	3539	3534	SAPS deployment 37 33.2N 010 21.5W	JC089-04	JC089-04-SAP2	pump depths @ 35, 110, 775, 1275, 2025, 3025, 3635 meters
JC089-05	**SHAK05**										
16/08/2013	18:40	16/08/2013	22:39	37° 36.26'	10° 41.50'	4670	4662	Piston core	JC89-05	SHAK-05-3P	recovery: 7.45 m
16/08/2013	22:39	17/08/2013	02:45	37° 36.26'	10° 41.51'	4672	4706	Megacore	JC89-05	SHAK-05-4M	recovery: 40,38,0,37,12.3,33,35,0 cm
17/08/2013	03:30	17/08/2013	07:23	37° 36.69'	10° 41.51'	4620	4647	CTD	JC89-05	SHAK-05-4CTD	water samples @5,20,55,250,600,1000,1300,2000,2500,3000,3700,4000,4551,4645.
17/08/2013	07:40	17/08/2013	12:15	37° 36.15'	10° 41.51'	4670	4690	Kasten core	JC89-05	SHAK-05-3K	recovery: 4.68 m, 6m barrel
JC089-06	**SHAK06**										
17/08/2013	16:23	17/08/2013	19:07	37° 33.68'	10° 08.53'	2645	2665	Megacore	JC89-06	SHAK-06-5M	recovery: 28, 29,30,28,25,30,30,26 cm
17/08/2013	19:36	17/08/2013	21:35	37° 33.68'	10° 08.53'	2643	2660	Box core	JC89-06	SHAK-06-4B	recovery: 47cm
17/08/2013	22:00	18/08/2013	00:26	37° 33.68'	10° 08.53'	2646	2673	Kasten core	JC89-06	SHAK-06-4K	recovery: 4.75 m, 6m barrel
18/08/2013	00:45	18/08/2013	03:18	37° 33.42'	10° 08.27'	2627	2615	CTD	JC89-06	SHAK-06-5CTD	water samples @5,25,40,55,100,250,475,750,1000,1100,1300,1500,1750,2000,2530,2625.
18/08/2013	03:18	18/08/2013	08:36	37° 33.6'	10° 08.34'	2635	2630	SAPS deployment	JC89-06	JC089-06-SAP3	pump depths @ 10, 55, 750, 1400, 2100, 2610 meters
18/08/2013	08:46	18/08/2013	11:08	37° 33.68'	10° 08.53'	2646	2671	Kasten core	JC89-06	SHAK-06-5K	recovery: 3.44m, 4-m barrel, Whole core sliced at 1 cm by ETH crew
JC089-03	**SHAK03**	revisited									
18/08/2013	13:35	18/08/2013	17:04	37° 42.45'	10° 29.55'	3740	3685	Kasten core	JC89-03*	SHAK-03-6K	recovery: 4.16m
JC089-07	**SHAK07**										
18/08/2013	19:27	18/08/2013	22:14	37° 50.91'	10° 09.16'	3100	3135	Megacore	JC89-07	SHAK-07-6M	recovery: 26,27,29,26,23,27,26,24 cm
18/08/2013	22:14	19/08/2013	01:48	37° 50.91'	10° 09.16'	3100	3081	Piston core	JC89-07	SHAK-07-4P	recovery: 10.19m
19/08/2013	02:35	19/08/2013	05:20	37° 50.88'	10° 09.17'	3080	3062	CTD	JC89-07	SHAK-07-6CTD	water samples @4,40,55,75,300,500,750,950,1100,1300,1500,2000,2500,2900.
19/08/2013	07:45	19/08/2013	10:12	30° 50.88'	10° 09.17'	3099	3137	Box core	JC89-07	SHAK-07-5B	recovery: 33-38cm
19/08/2013	10:12	19/08/2013	12:55	37° 50.88'	10° 09.17'	3100	3132	Kasten core	JC89-07	SHAK-07-7K	recovery: 4.24m

Table 3 (cont.) Station activities log.

Start Date	Start Time	End Date	End Time	Latitude	Longitude	Water depth	Wire out	Event Description All times Local time (GMT +1 to GMT +2))	Station name	Activity identifier	Comment
JC089-08	**SHAK08**										
19/08/2013	13:55	19/08/2013	17:00	37° 46.90'	10° 02.80'	2619	2543	Megacore	JC89-08	SHAK-08-7M	recovery: 31,29,31,31,18,28,31,30 cm
19/08/2013	17:00	19/08/2013	19:55	37° 46.90'	10° 03.80'	2619	2590	Piston core	JC89-08	SHAK-08-5P	recovery: 9.2m
19/08/2013	19:55	19/08/2013	22:28	37° 46.90'	10° 02.80'	2613	2646	Box core	JC89-08	SHAK-08-6B	no record of recovery will have to measure in sampled tubes
19/08/2013	22:55	20/08/2013	01:42	37° 47.71'	10° 02.82'	2592	2580	CTD	JC89-08	SHAK-08-7CTD	water samples @5,30,50,70,150,200,450,800,1000,1250,1500,1750,2000,2250,2500,2612.
20/08/2013	02:16	20/08/2013	07:05	37° 46.68'	10° 02.28'	2607	2592	SAPS deployment	JC89-08	JC089-08-SAP4	pump depths @ 5, 65, 795, 1495, 2145, 2577 meters
20/08/2013	07:48	20/08/2013	10:05	37° 46.88'	10° 02.79'	2618	2640	Kasten core	JC89-08	SHAK-08-8K	recovery: 4.15m
JC089-09	**SHAK09**										
20/08/2013	13:00	20/08/2013	15:05	37° 49.83'	09° 49.30'	2323	2320	Megacore	JC89-09	SHAK-09-8M	recovery: 40.3, 38.5, 39.8, 0, 34,34.4, 40.5, 39.4 cm
20/08/2013	15:05	20/08/2013	17:36	37° 49.28'	09° 49.28'	2323	2300	Piston core	JC89-09	SHAK-09-6P	recovery: 9.02 m
20/08/2013	17:36	20/08/2013	19:45	37° 49.82'	09° 49.32'	2323	2327	Box core	JC89-09	SHAK-09-7B	no record of recovery will have to measure in sampled tubes
20/08/2013	20:25	20/08/2013	22:06	37° 49.82'	09° 49.32	2323	2346	Kasten core	JC89-09	SHAK-09-9K	recovery: 5.02 m
20/08/2013	22:50	21/08/2013	01:00	37° 49.99'	09° 49.09'	2303	2308	CTD	JC89-09	SHAK-09-8CTD	water samples @5,20,60,100,250,450,500,700,1000,1250,1400,1500,1750,2000,2200 m.
21/08/2013	01:42	21/08/2013	06:16	37° 49.5'	09° 52.14'	2316	2311	SAPS deployment	JC089-09	JC089-09 SAP5	pump depths @ 10, 50, 500, 1400, 1650, 2291 meters
JC089-10	**SHAK10**	**MD2041**									
21/08/2013	10:15	21/08/2013	11:24	37° 50.00'	09° 30.65'	1127	1144	Box core	JC89-10	SHAK-10-8B	recovery: 55 cm
21/08/2013	11:24	21/08/2013	12:54	37° 50.50'	09° 30.65'	1127	1150	Megacore	JC89-10	SHAK-10-9M	recovery: 0 39,41,45,0,13,50,42 cm
21/08/2013	12:54	21/08/2013	14:16	37° 50.00'	09° 30.65'	1127	1150	Kasten core	JC89-10	SHAK-10-10K	recovery: 4.18m
21/08/2013	15:30	21/08/2013	17:22	37° 50.00'	09° 30.65'	1127	1127	Piston core	JC89-10	SHAK-10-7P	recovery: 8.08m, 2 sections imploded
21/08/2013	18:02	21/08/2013	19:53	37° 50.50'	09° 30.65'	1127	1100	CTD	JC89-10	SHAK-10-9CTD	water samples @5,20,35,50,70,100,200,350,450,700,800,900,1020,1100,1120 m.
21/08/2013	20:40	21/08/2013	23:55	37° 49.98'	09° 30.66'	1130	1114	SAPS deploy,emt	JC089-10	JC089-10-SAP6	pump depths @ 10, 45, 375, 525, 700, 1105 meters
JC089-11	**SHAK11**										
22/08/2013	13:47	22/08/2013	14:35	37° 51.52'	09° 20.15'	617		Box core	JC89-11	SHAK-11-9B	recovery: 30-32cm
22/08/2013	14:35	22/08/2013	15:45	37° 51.51'	09° 20.15'	628	626	Megacore	JC89-11	SHAK-11-10M	recovery: 0,14,22,24,16,23,0,22 cm
22/08/2013	15:45	22/08/2013	16:51	37° 51.51'	09° 20.14'	618	615	Gravity core	JC89-11	SHAK-11-1G	recovery: 4.58 m
22/08/2013	17:19	22/08/2013	18:24	37° 51.51'	09° 20.14'	620	600	CTD	JC89-11	SHAK-11-10CTD	water samples @5,15,25,100,200,330,516,610 m.
JC089-12	**SHAK12**										
22/08/2013	20:15	22/08/2013	21:52	37° 59.36'	09° 35.41'	1607	1630	Box core	JC89-12	SHAK-12-10B	recovery: 47 cm
22/08/2013	21:52	22/08/2013	23:58	37° 58.35'	09° 35.91'	1611	1628	Megacore	JC89-12	SHAK-12-11M	recovery: 39.5,42,41,0,34,40.5,38,0 cm
22/08/2013	23:58	22/08/2013	01:03	37° 59.36'	09° 35.91'	1600	1627	Gravity core	JC89-12	SHAK-12-2G	recovery: 5.35 m
22/08/2013	01:34	22/08/2013	03:08	37° 59.34'	09° 35.91'	1599	1600	CTD	JC89-12	SHAK-12-11CTD	water samples @2,20,40,100,220,380,500,800,1150,1290,1505,1593 m.
JC089-13	**SHAK13**										
23/08/2013	04:12	23/08/2013	05:36	37° 56.12'	09° 35.11'	1442	1455	Box core	JC89-13	SHAK-13-11B	recovery: 55 cm
23/08/2013	05:36	23/08/2013	07:42	37° 56.12'	09° 35.10'	1440	1458	Gravity core	JC89-13	SHAK-13-3G	recovery: 5.19 m
23/08/2013	07:42	23/08/2013	09:20	37° 56.12'	09° 35.10'	1448	1459	Megacore	JC89-13	SHAK-13-12M	recovery: 6.5,41,42,0,34,40,38,0 cm
23/08/2013	09:50	23/08/2013	11:54	37° 56.12'	09° 35.12'	1413	1460	Piston core	JC89-13	SHAK-13-8P	recovery: 7.95m
23/08/2013	11:54	23/08/2013	13:30	37° 56.12'	09° 35.10'	1434	1427	CTD	JC89-13	SHAK-13-12CTD	water samples @5,35,50,100,300,450,600,825,900,1050,1336,1428.
JC089-14	**SHAK14**										
23/08/2013	16:41	23/08/2013	18:42	37° 50.16'	09° 43.16'	2063	2095	Box core	JC89-14	SHAK-14-12B	recovery: 40-46 cm
23/08/2013	18:42	23/08/2013	20:42	37° 50.16'	09° 43.16'	2063	2092	Gravity core	JC89-14	SHAK-14-4G	recovery: 5.13 m
23/08/2013	20:42	23/08/2013	22:54	37° 50.16'	09° 43.61'	2062	2070	Megacore	JC89-14	SHAK-14-13M	recovery: 38.5,40,42,39.5,41.5,41.5,42,39.5 cm
23/08/2013	22:54	24/08/2013	01:45	37° 50.16'	09° 43.61'	2063	2090	Piston core	JC89-14	SHAK-14-9P	recovery: 9.28 m
24/08/2013	01:45	24/08/201 3	03:40	37° 56.12'	09° 35.10'	1434	2041	CTD	JC89-13	SHAK-13-12CTD	water samples @5,35,50,100,300,450,600,825,900,1050,1336,1428 m.
JC089-11	**SHAK11**	**revisited**									
24/08/2013	06:58	24/08/2013	08:18	37° 51.51'	09° 20.12'	618	575	Piston core	JC89-11*	SHAK-11-10P	recovery: 3.43 m, sandy
JC089-15	**SHAK15**										
24/08/2013	10:24	24/08/2013	11:08	37° 49.38'	09° 11.00'	405	400	Day grab	JC89-15	SHAK-15-1Gr	recovery: A few spoons full, but enough

*note XBTs and XCDs deployed during underway seismic operations are provided in a separate table.

7. Operations

7.1 Geophysics

7.1.1 Personnel:

Nicky White (njw10@cam.ac.uk), Matthew Falder & Charlotte Schoonman
Ross Parnell-Turner (post-cruise processing)

Bullard Laboratories, Department of Earth Sciences
University of Cambridge Madingley Rise Madingley Road Cambridge
CB3 0EZ UK

Gabriela Carrara (gcarrara67@gmail.com)
Divisão de Geologia e Georecursos Marinhos,
Estrada da Portela, Zambujal, Apartado 7586, 2721-866 Alfragide, Portugal

7.1.2 Seismic data collection and processing

An important purpose of JC089 was the acquisition of crossing seismic reflection profiles at potential IODP drilling sites. In advance of the cruise, a database of legacy seismic reflection surveys, both academic and industrial, was compiled and examined. This database helped to determine the general location of optimal coring and drilling areas and to guide the acquisition strategy for JC089. A 10-day acquisition program was developed in advance of the cruise. This program was modified and optimized during the progress of the cruise. A total of 755 line kilometres of seismic reflection profiles were acquired using a 3-kilometre streamer and a small airgun source consisting of two generator-injector guns (Fig. 5 & 6). There were significant problems with using two guns and the bulk of the survey was acquired using a single gun. Despite this problem together with weather downtime issues, data quality is generally good. Penetration of 3–4 seconds two-way travel time has been achieved at high fold with excellent resolution. The resulting set of crossing lines will provide an ideal basis for revising and resubmitting the IODP proposal which this cruise was designed to underpin. An important by-product of this seismic survey is imaging of the water column which has been calibrated by a combination of disposable hydrographic probes and CTD casts.

The seismic acquisition system consisted of a 3 km streamer, with 240 hydrophones at a group interval of 12.5 meters (Fig. 5). The near offset was 154.5 meters. The streamer was towed at 7 meters depth, steered by 8 Sercel Nautilus birds. Record length was 14 seconds, with a sampling rate of 1 kHz (1 ms sampling.) The source was initially two 350 inch^3 Generator-Injector (GI) guns, towed at 5 meters depth. However, after issues with the synchronisation of the guns, which caused ringing in the data, this configuration was reduced to one gun. Air pressure was 3000 psi, which provided good penetration even with only one gun, and the improvement in quality of the data, once source ringing was eliminated was marked.

The initial synchronisation problem was isolated to being due to cross-wired hydrophone sensors, feeding the Big Shot software package incorrect information, and causing asynchronous gun firing, with a variable delay between guns of between 7 and 17 millisecond, with the delay increasing shot on shot over a period of 30 shots, before ‘snapping’ back to the smaller value of 7 ms. This pathology significantly impacted the quality of the data since individual CMP gather would have multiple different delays, leading to loss in vertical resolution.

The cause of the second synchronisation issue, where the guns fired with a constant delay of around 16 ms, remains unknown. The airguns were checked, solenoids replaced, and wiring checked and re-checked. After devoting significant time to this issue, and several trials, it was decided to continue the survey using only one GI gun, as the high pressure compressed air provided a sufficient signal to achieve good penetration.

Initial processing on board was performed using the Seismic Unix (SU) software package. Incoming data were copied to the ship’s system every 5 minutes, where automated scripts would then retrieve the SEGD files, and convert them on a shot-by-shot basis to .su format (Seismic Unix native format.) This automated system allowed manual near- real-time assessment of the data quality. Whilst this method worked reasonably well, the lack of live QC screens in the seismic acquisition set-up no doubt increased the time spent surveying with airgun synchronisation problems.

Once the data were in native SU format, the processing flow consisted of a low pass filter from 8 Hz to 12 Hz to remove swell noise, followed by a simple 1D geometry application, and CMP assignation. Velocity picking was performed on semblance plots from supergathers of between 3 and 5 CMPs, approximately every 400 CMPs (equivalent to 1500 meters). A clear semblance peak was commonly visible throughout the sediment pile, suggesting high quality and coherent data. Picked velocities were then used to stack the data. A trace mix was often used to increase the lateral continuity of reflections, and as a quick way to reduce noise caused by rough weather. In future flows, the noise will be isolated in a more sophisticated manner, however for the purposes of site selection, and quality control, this was sufficient.

Display of data was achieved directly on-screen using the tools available in SU, whilst for printouts of long seismic lines, the free software Inkscape was used to stitch together multiple smaller seismic images into one long line (Fig. 7).

Following the cruise, seismic processing was carried out using *SeismicUnix* and Schlumberger's *Omega2* software packages (Cohen & Stockwell, 2012). Processing began with assignment of common-midpoint (CMP) numbers based on experimental geometry and velocity of the vessel. Next, a 12 Hz high-pass filter with a roll-off of 24 dB per octave was applied to remove low-frequency swell noise. An accurate velocity model, required to perform a normal moveout correction, was constructed by hand-picking individual velocity functions every 300 CMPs (about 1875 m). Velocity picks were made with the aid of semblance plots, multi-velocity function stacks (9 functions per location) and common-offset gathers constructed for each analysis location. Velocity picks were then interpolated and smoothed to produce a continuous model. Normal moveout correction was then carried out. After stacking, a multichannel dip filter was applied in frequency-wavenumber domain. This filter is defined by a four-point polygon in f-k space, and used to remove any remaining coherent noise. Next, a post-stack Stolt migration was performed with a constant acoustic velocity of 1500 m/s. Finally, trace balancing and time-dependent gain functions were applied prior to generating final plots. The processed lines are presented in Appendix I.

Cohen, J. K. and Stockwell, Jr. J. W., (2012), CWP/SU: Seismic Un*x Release No. 43R3: an open source software package for seismic research and processing, Center for Wave Phenomena, Colorado School of Mines.

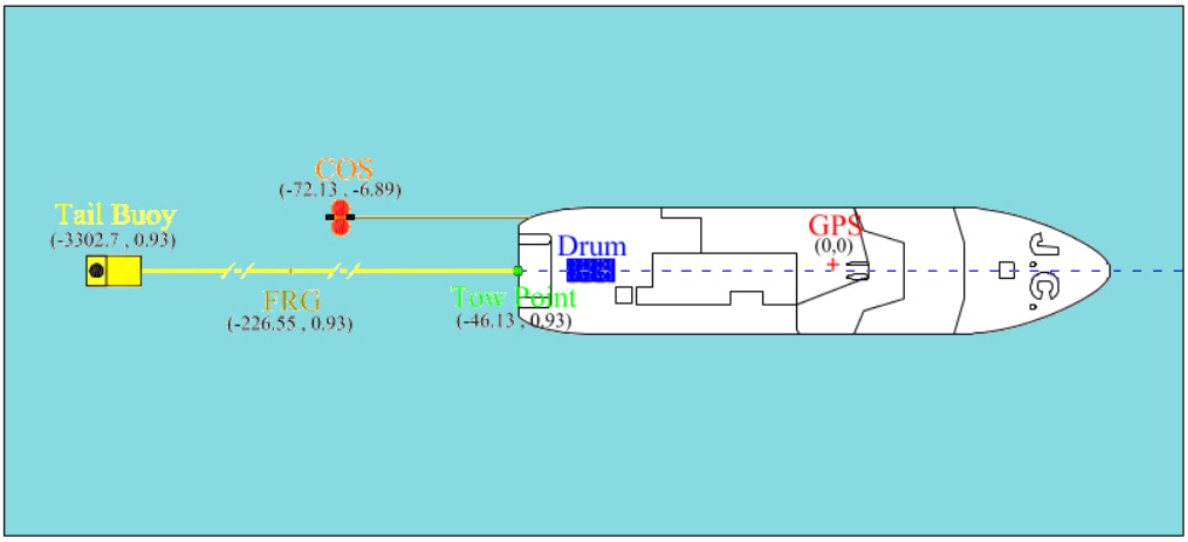


Fig. 5. Configuration of seismic acquisition system for JC089.

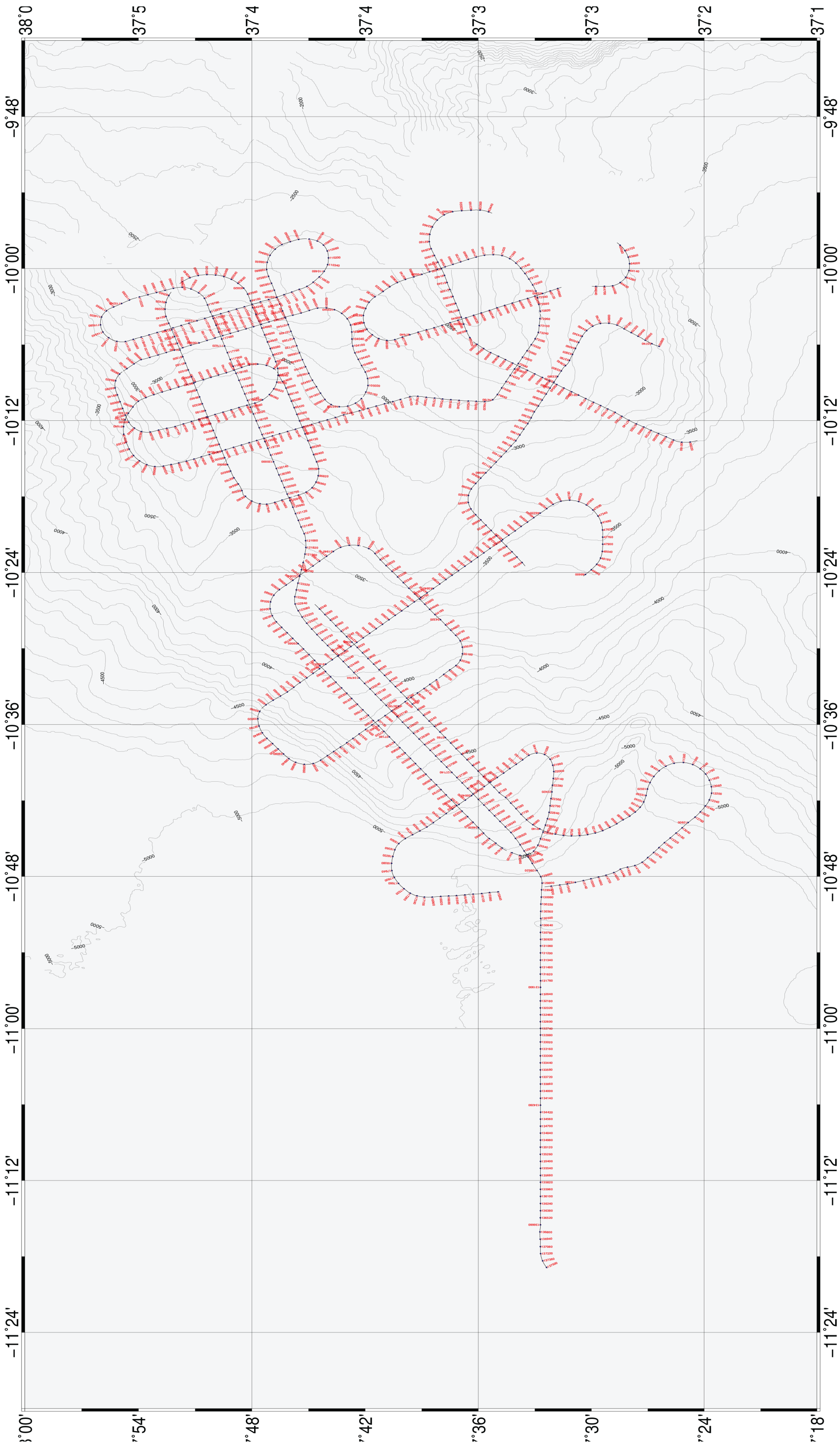
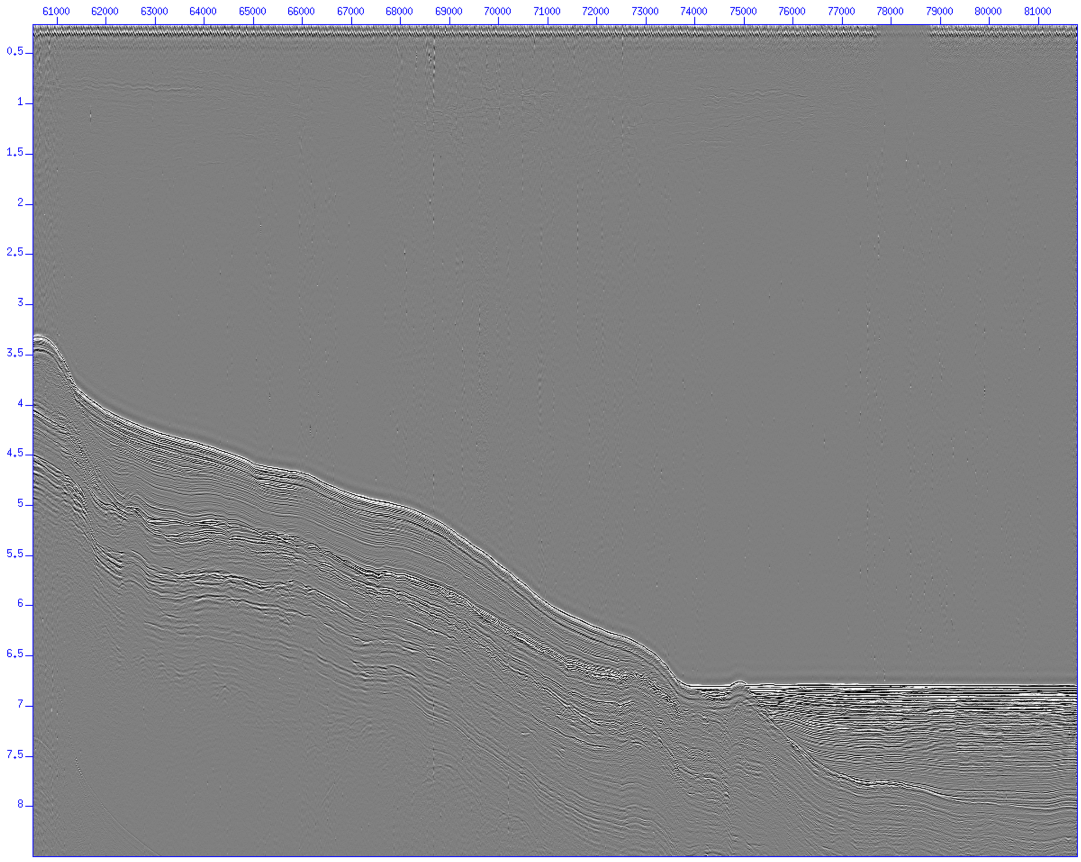


Fig. 6. Bathymetric map showing seismic survey acquired during JC089. Red labels = common mid-points.

Figure 7: Portion of seismic data acquired during JC089 which crosses continental margin.



7.1.3 Underway Geophysics

John Seddon (john.seddon@noc.ac.uk), IT & Underway Marine Technician

Kongsberg EA600 12 kHZ single beam echo sounder.
The EA600 single beam echo sounder was run throughout the cruise. The EA600 was used with a constant sound velocity of 1500 ms^{-1} throughout the water column to allow it to be corrected for sound velocity in post processing. As well as depths being logged to the Techsas and Level-C data loggers, files were saved as .BMP images and in raw Kongsberg format.

EK60 Echo Sounder.
The EK60 fisheries echo sounder was run as it provided valuable water column information for the scientists using seismic data to look at structures in the water. The 18, 38, 120 and 200 kHz transducers were used. The 70 kHz transducer was not used in case it interfered with the vessel mounted ADCP, whose data was considered more useful. Raw and processed data were logged using settings from the previous cruise that the EK60 was used on (JC87 and probably configured on JC77). The sound velocity had been not been changed from the previous cruise and was left at 1511.7 ms^{-1}, whereas the typical sound velocity at 5 m below the surface on this cruise was 1524 ms^{-1}.

Kongsberg EM120 Deep Water Multi-beam echo sounder.
The EM120 multi-beam echo sounder was run throughout the cruise to provide general depth information in addition to the single beam system. Data was logged in Kongsberg .all format. The centre beam depth was logged to Techsas and Level-C.
The calibration of the EM120 was checked at the start of the cruise on August 5th in a water depth of around 2500 m. An accurate sound velocity profile was obtained at the site immediately beforehand using the SVP profiler attached to the CTD frame. The lines shown in Table 4 were run and the offset angles before calibration are shown in Figure 8a. For the roll calibration two lines were run over the same line in opposite directions on a flat area of sea bed. The SIS calibration module was used and the roll angle for the attitude 1 sensor (the POSMV) was changed from 0.1° to 0.15°. For the pitch calibration two lines were run over the same line in opposite directions but over a feature on the sea bed. Features were identified is SIS' waterfall display. Several lines were attempted to find a suitable object for the calibration but it was discovered that the waterfall display distorted the received data and exaggerated features. Eventually lines 63 to 65 were run. The features were not distinct enough to improve on the existing pitch calibration, which appeared to be accurate. The final calibration offsets are shown in Figure 8b.

Table 4- EM120 calibration lines on 5th August.

Time	Latitude	Longitude	Line	Comment
20:15	41° 00.54' N	009° 44.966' W	51	Start of southbound roll line
20:27	40° 59.53' N	009° 44.968' W	52	End of southbound roll line
20:43	40° 59.613' N	009° 44.951' W	54	Start of northbound roll line
20:55	41° 00.604' N	009° 44.968' W	55	End of northbound roll line
23:27	40° 56.621' N	009° 43.005' W	62	Start of northbound pitch line
			63	Continuation of pitch line
00:12	41° 00.393' N	009° 43.007' W	64	End of line, features weren't as apparent as had been hoped for
00:23	41° 00.094' N	009° 43.018' W	65	Start of southbound pitch line
00:42	40° 58.484' N	009° 43.005' W	66	End of southbound pitch line

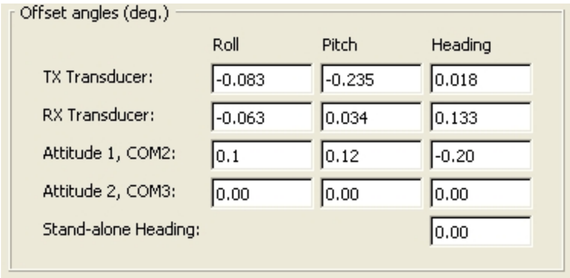


Figure 8a - EM120 angular offsets before calibration.

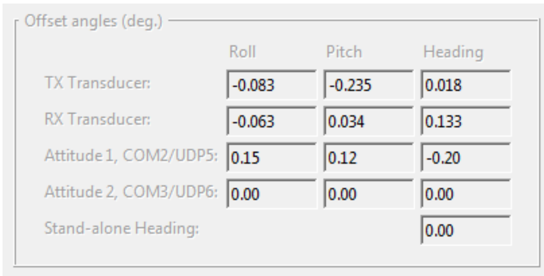


Figure 8b - EM120 angular offsets after calibration.

Kongsberg SBP120 Sub Bottom Profiler.

The Sub Bottom Profiler (SBP) was run for much of the cruise, although it was often referred to by the name of its predecessor, the 3.5 kHz. Data was recorded in SEG-Y format. The data was organised into a few directories, but there is little structure to these and so it is probably best to copy all of the data into one directory and choose files based on their modification time. The SBP receives a depth, and a slope, range and velocity input from the EM120 multi-beam echo sounder. When the vessel was pitching the EM120 had a poor signal strength and lost bottom track. The SBP would often then acquire data over a time interval that did not include reflections from the sea bed. As soon as the EM120 reacquired the sea bed then the SBP would record data over the correct interval.

The SBP configuration used is shown in Figure 9a. Five filters were set-up for the display on the screen. The order of these filters is shown in Figure 9b. The settings for the five filters are shown in Figures 9c-g. These filter settings only affect the display on the screen. The SEG-Y files contain the raw data. The raw data can be played back in the Kongsberg SBP software or any other SEG-Y viewer.

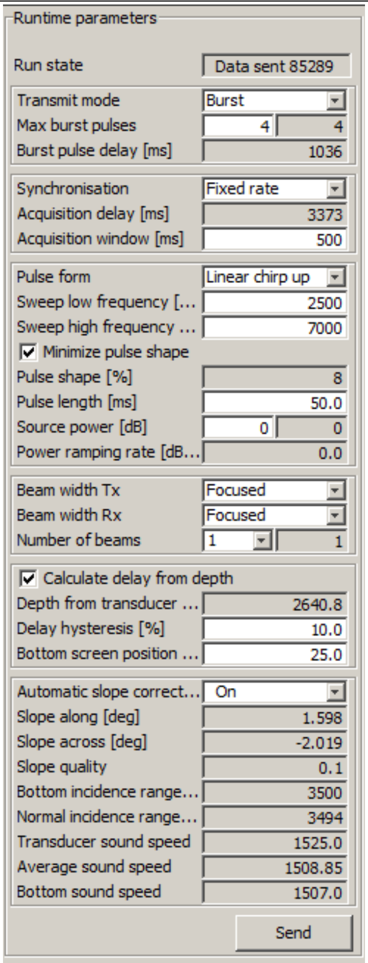


Figure 9a - SBP runtime parameters.

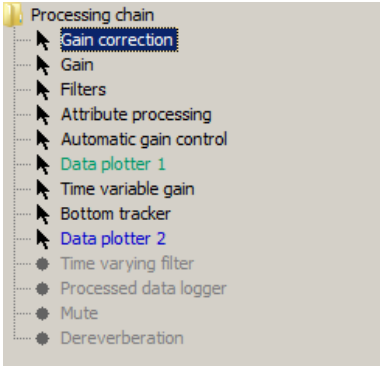


Figure 9b - SBP processing options for the display on the screen.

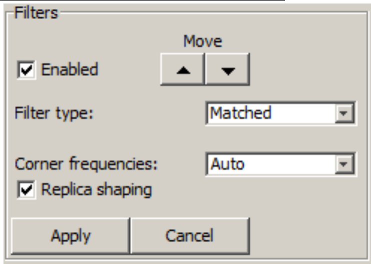


Figure 9c - SBP display filters settings.

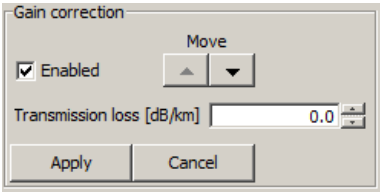


Figure 9d - SBP display gain correction settings.

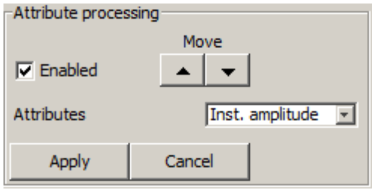


Figure 9e - SBP display attribute processing options.

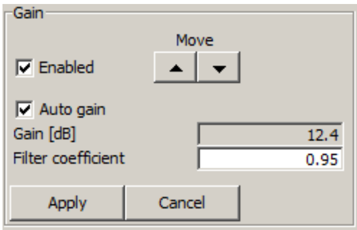


Figure 9f - SBP display gain settings.

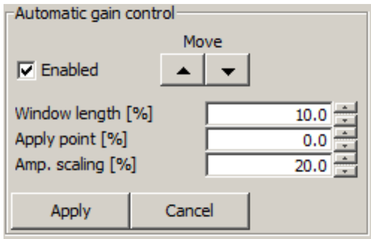


Figure 9g - SBP display automatic gain control settings.

Sound Velocity Profiles.

The sound velocity profiles listed in Table 5 were used in the EM120 multibeam swath and USBL systems. They are included on the data disk. The first profile was left in the system after the previous cruise in Irish waters. Subsequent profiles beginning 201308 were measured with a Valeport Midas serial number 22355 attached to the CTD frame or to the core warp. The Valeport Midas records, time, depth, sound velocity and temperature. The calibration certificate is included on the data disk. Profiles beginning JC089_ were derived from CTD data. The installation time of each profile in the EM120 is shown in Table 5.The files were sorted and thinned in the Kongsberg sound velocity editing software. The raw data files that also include temperature have a filename of the form FILEX.000 where X is an single digit integer.

Table 5 - Sound velocity profile installation times.

Installation Time	Profile	Location	Time Recorded
Start of cruise	Unknown profile left from the previous cruise	Unknown	Unknown
5th August 19:15	20130805_thinned.asvp	41° 00.175' N 009° 44.886' W	5th August 16:14
8th August 07:20	20130807_sorted_thinned.asvp	37° 42.541' N 010° 29.558' W	7th August 17:49
17th August 07:10	20130816_sorted_thinned.asvp	37° 20.863' N 011° 22.745' W	16th August 08:41
20th August 07:03	20130820_sorted_thinned.asvp	37° 47.710' N 010° 02.796' W	19th August 21:18
21st August 05:02	CTD_Derived\20130821\JC089_08_thinned.asvp	37° 50.000' N 009° 49.100' W	20th August 20:39
21st August 22:04	20130821_sorted_thinned.asvp	37° 50.000' N 009° 30.649' W	21st August 16:02
23rd August 12:45	CTD_Derived\20130823\JC089_12_thinned.asvp	37° 56.120' N 009° 35.100' W	23rd August 10:00

An additional two sound velocity profiles were taken but not used in the swath or USBL systems, these are described in Table 6.

Table 6 - Sound velocity profiles acquired not used in the multibeam or USBL systems.

Profile File	Location	Time	Notes
20130823\FILE8.000	37° 51.508' N 009° 20.137' W	15:18 22nd August	With CTD 10
20130824\FILE2.000	37° 49.385' N 009° 11.000' W	09:16 24th August	On core warp

75 kHz hull mounted ADCP system.

The 75 kHz ADCP system was run during the cruise. The raw data files and configurations are included on the data disk. The scientific party had no particular requirements for the data and so a typical configuration from the previous cruise was used. Bottom tracking was enabled from the start of the cruise until 19:02 on 29th July. No 150 kHz ADCP was fitted to the vessel during this cruise as the transducer was being repaired at the manufacturer.

Gravity Meter.

Gravity meter S40 was installed on the vessel during the mobilisation. It was run throughout the cruise but with tie-ins performed in Southampton on 26th (for NMFSS training) and 27th July and in Vigo on 31st July and probably again on 27th August. The tie-in was performed using land meter G484. The tie-in on 26th July was performed by NMFSS technicians who had never done one for training purposes, the data acquired on this day has not been checked by anyone else. No problems were encountered on 26th July and so despite the technicians' lack of experience the data should be good.

During the tie-in in Vigo on 31st July a discrepancy was found in the base station data. The text describes the base station as being 1.5 m east of the hydrant and 1.3 m from the edge of the quay but the diagram has the base station as being 1 m from the hydrant and 0.8 m from the edge of the quay. The tie-in was performed with the meter in the position given in the diagram.

The PC clock on S40 was found to drift. The PC's time was accurately set on July 26th and again on July 27th before the base station. The time stamps in the data files are given by the PC's clock, but the time stamps in the NetCDF files are given by the Techsas data logger, which is set to GPS time using the NTP protocol. A record of the PC's clock's drift is given in Table 7.

Table 7- Gravity Meter PC times during the cruise.

Date	Julian Day	PC Time	Actual Time
27th July	208	10:00:00	10:00:00
31st July	212	09:22:50	09:23:00
15th August	227	09:09:17	09:10:00
17th August	229	14:51:11	14:52:00
21st August	233	22:50:01	22:51:00
25th August	237	13:27:54	13:28:00

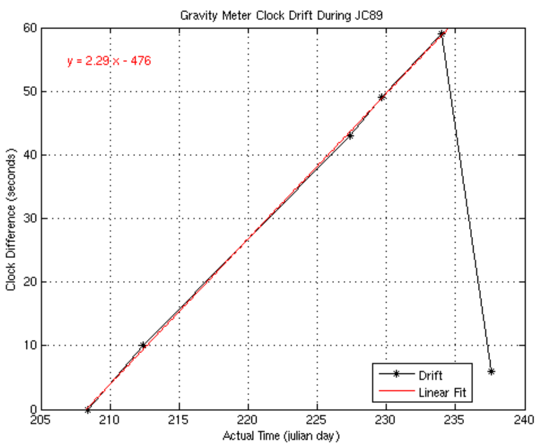


Figure 8 - Gravity Meter clock drift with the data points marked in black and the linear approximation in red.

Figure 8 shows the clock drift as a function of time with a linear fit. The clock is drifting at a rate of 2.3 seconds per day until sometime between 21st and 25th August, following a trend that is linear when it is considered that the difference between the gravity PC's time and actual time can only be measured with an accuracy of 1 second. It is not known why the sudden jump occurred towards the end of the cruise. The gravity data from the NetCDF files should be used rather than the gravity files (\JC89\Ship_Systems\TECHSAS\NetCDF on the data disk rather than

\JC89\Ship_Systems\Gravity_Meter) because these values have been time stamped by the Techsas data logger, which is synchronised to the GPS clock.

Magnetometer.

The Marine Magnetics Sea Spy magnetometer was brought on the cruise and was planned to be deployed throughout the seismic sections of the cruise. The weather was at the top end of what the seismic streamer could be deployed in and there were problems keeping the guns and streamer apart. It was considered too risky to deploy the magnetometer at the same time. Magnetometer serial number 13358 was deployed on 7th August to test the cabling and winch. The data is included on the data disk, but it was not possible to set the magnetometer's clock and so the time stamps are from July and no positions were recorded.

On 15th August the weather and sea conditions had moderated and so the magnetometer was deployed. The magnetometer was deployed to a lay-back of 300m, but the depth sensor was found to be giving values of 0.0 m and so was recovered. Magnetometer serial number 13428 was deployed instead, again with a lay-back of 300 m. Magnetometer data was recorded between 14:05 on 15th August (line 5978 in 20130816_magnetometer.csv, magnetometer position 37.80464° N 10.17059° W) and 05:28 on 16th August (line 116819 in 20130816_magnetometer.csv, magnetometer position 37.51588° N 11.33203° W). Data was recorded in Marine Magnetics BOB binary database format and also exported as a comma separated variable (CSV) ascii file. Unfortunately due to a bug in BOB the hour is not included in the times in the CSV file. The vessel position is included and so times can be calculated using the minute and second from the time and the vessel's latitude and longitude. The magnetometer position is also included in the file, which incorporates the 300 m lay-back.

XBT and XCTD.

XBTs and XCTDs were frequently deployed by the scientists during seismic data acquisition. The Windows XP based computer that the WinMK21 XBT acquisition software was being run on failed to start when it was rebooted on 10th August. A Windows 7 laptop running the latest version of WinMK21 software (version 3.0.3) was then used instead. The longitude was sometimes displayed and recorded incorrectly in this version of the software. The affected data files were T5-00028.RDF, T5-00029.RDF, T5-00031.RDF, T5-00032.RDF, T5-00033.RDF, T5-00037.RDF and T5-00038.RDF. The software had been set to use GGA and RMC NMEA position sentences but only RMC strings were being fed to it. When the GGA option was removed then the correct position was included in the files.

Either the launcher or the wiring was damaged on 13th August and three deployments contain invalid data: T5-00047.RDF, T5-00048.RDF and T5-00049.RDF. The first of these casts contain wildly inaccurate data. The second two files show a small decrease in resistance, the cause of which is not known. The wiring in the junction box on the starboard deck was replaced, the connections in the main lab were reterminated and the launcher was swapped for a spare due to damage to its lead. All data recorded after these changes appears to be good. These repairs caused a six hour gap in XBT casts.

Several other casts failed due to faulty probes or the cable getting caught on the streamer. The XBT log sheet has been included in the XBT directory on the cruise data disk and should be consulted for details of these.

7.2 Coring Operations

7.2.1 Personnel:

Nick McCave (mccave@esc.cam.ac.uk)
David Hodell (dah73@cam.ac.uk)
Luke Skinner
Simon Crowhurst
Matthew Falder
Julia Gottschalk
John Nicholson
Natalia Vazquez Riveiros
Jenny Roberts
Charlotte Schoonman
Nicky White

Department of Earth Sciences
University of Cambridge
Downing Site
Cambridge CB2 3EQ

Celia Santos
Catarina Cavaleiro
Gabriela Carrara

Instituto Português do Mar e da Atmosfera,
Divisão de Geologia e Georecursos Marinhos,
Estrada da Portela, Zambujal, Apartado 7586, 2721-866 Alfragide, Portugal

Clayton Magill
Daniel Montlucon

Geologisches Institut
NO G 59
Sonneggstrasse 5
8092 Zürich
Switzerland

7.2.2 Specific Aims

The objectives of sediment coring were two fold: i.) to meet site survey requirements for IODP proposal 771-Full; and ii.) to study sedimentary processes (e.g., sediment provenance and focusing, bioturbation, etc.) and calibrate geochemical and sedimentological proxies on the SW Iberian Margin.

We recovered 10 piston cores, 12 box cores, 10 kasten cores, 4 gravity cores, 13 megacores, and 1 grab sample. Station locations are given in Table 3 and shown in

Figures 2 and 3. Table 8 presents a summary of the cores recovered at each station. The long cores span the last deglaciation and range in water depth from 405 to 4670 m, intersecting each of the major subsurface water masses on the Iberian Margin (Figure 9) constituting as yet one of the most complete vertical transects of sediment cores from a continental margin. The cores will be used to characterise surficial sediment (seafloor lithology), sedimentation rates, and assess the suitability of sediments for palaeoceanographic reconstruction. In addition, we will use the cores to reconstruct bathymetric transects of geochemical properties (e.g., oxygen isotopes, Mg/Ca, benthic $\delta^{13}C$, radiocarbon) to infer past changes in water mass distributions from the last glacial period, through the deglaciation, and into the Holocene.

Table 8. Summary of cores taken at each station.

JC 89 Station positions

		Old reference	Lat (°' N)		Long (°' W)		Depth (m)	Box	Piston	Megacore	Kasten	Gravity	CTD	SAP
JC089-1	SHAK1	(Morena-A)	41	0.00	9	28.50	1299	1B						
JC089-2	SHAK2	(Morena-B)	41	0.17	9	44.87	2518	2B		1M			1	
JC089-3	SHAK3	(SHACK-6)	37	42.54	10	29.56	3735	3B	1P	2M	6K		2	1
JC089-4	SHAK4	(SHACK-5)	37	35.15	10	21.89	3477		2P	3M	2K		3	2
JC089-5	SHAK5	(SHACK-7)	37	36.26	10	41.50	4670		3P	4M	3K		4	
JC089-6	SHAK6	(SHACK-4)	37	33.68	10	8.53	2642	4B		5M	4K&5K		5	3
JC089-7	SHAK7	(SHACK-1)	37	50.91	10	9.10	3099	5B	4P	6M	7K		6	
JC089-8	SHAK8	(SHACK-3)	37	46.91	10	2.80	2619	6B	5P	7M	8K		7	4
JC089-9	SHAK9	(SHACK-2)	37	49.82	9	49.29	2323	7B	6P	8M	9K		8	5
JC089-10	SHAK10	(MD95-2041)	37	50.00	9	30.65	1127	8B	7P	9M	10K		9	6
JC089-11	SHAK11		37	51.51	9	20.16	618	9B	10P	10M		1G	10	
JC089-12	SHAK12		37	59.36	9	35.91	1607	10B		11M		2G	11	
JC089-13	SHAK13		37	56.15	9	35.10	1440	11B	8P	12M		3G	12	
JC089-14	SHAK14		37	50.16	9	43.61	2063	12B	9P	13M		4G	13	
JC089-15	SHAK15		37	49.38	9	11.00	405					1GR		

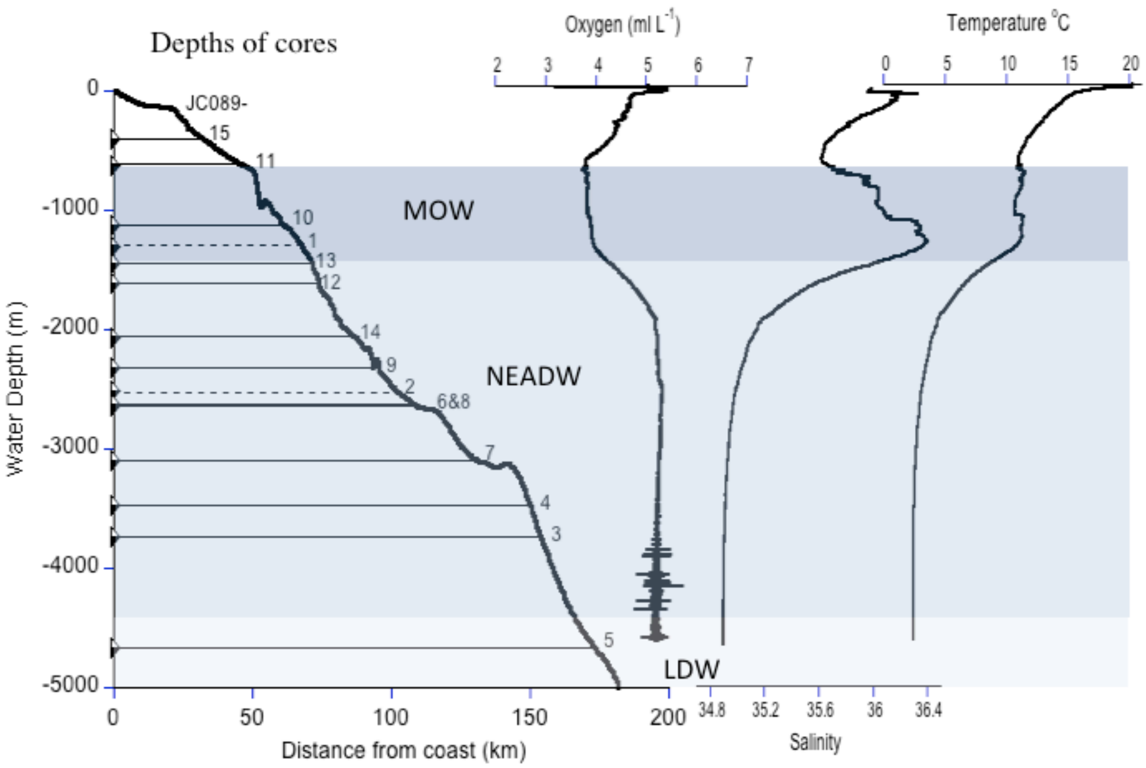


Fig. 9. Position of coring stations as a function of distance from coast and water depth relative to oxygen, temperature, and salinity at the deepest site (SHAK-5 at 4670 m water depth). MOW = Mediterranean Outflow Water; NEADW = Northeast Atlantic Deep Water; LDW = Lower Deep Water

7.2.3 Core naming protocol.

STATIONS are numbered sequentially; JC89 – **nn**.
ACTIVITIES: Cores are numbered sequentially for each type eg -1B, -2B; -1K, -2K, etc. The **station number** is inserted as the second element prefixed by the 4-letter campaign designator SHAK-; (e.g. core SHAK-**08**-5P at station JC89-**08**).
SUFFIXES –nB = Box core, -nK = Kasten core, -nM = Megacore, -nP = Piston core, -nG = Gravity core, -nGr = Grab sample.
DEPTHS are from echo sounder in metres which, because CTD and SVP probes were run giving us depth-dependent sound speed, are essentially 'corrected' depths. For cores it is depth at time of impact on the bottom.
POSITIONS are degree and minute with decimal (not seconds), at time of impact on the bottom for cores.
SAMPLES are designated by the core number and sample depth. Megacore tubes have letters for each tube position (arbitrary but the same for a given position on this cruise), e.g. SHAK-04-3M-C, 2-3cm (i.e. station 4, megacore 3, position C, 2-3 cm slice).

We note that the SHAK site numbers employed in this report are not the same as the former "SHACK" designations used in IODP proposal 771 Full.

7.2.4 Corers employed

Box Coring

The instrument was the standard "Sandia Mark 3" (known at NMF-SS Marine Facilities as the 'SMBA box corer') 50 x 50 x 50-60 cm spade corer after Hessler & Jumars' (1974) modification of the USNEL box corer. The box corer proved reliable as ever. We rarely failed to obtain a sample and did not bend the box, despite landing occasionally on current-scoured ground. Average recovery was 43 cm (omitting 1B on hard ground). Table 9 shows the locations, depths, recovery and comments for each of the 12 box cores taken during JC89.

The sub-sampling procedure was as follows:

1. A series of tubes were first inserted in the mud: several 110 mm (i.d.) core liner tubes, a tube for oxygen micro electrode work, and other tubes for organic geochemistry. We also put in a pre-drilled mega corer tube for pore water extraction by Rhizon in some box cores. Portuguese 10 cm and 5 cm square x 1 cm deep surface scrape guides were used (Fig. 8). As the cruise progressed insertion of tubes became a popular pastime – see Fig. 9)
2. The topmost 2 cm of the remainder of the box core surface was scraped and bagged as 'bulk core-top' for sedimentological and geochemical determinations.
3. The 330 mm long x 150 mm wide x 25 mm thick styrene trays employed for kasten core sub-sampling were routinely used to obtain a vertical sub-sample from the top section of each box core once the side panel had been removed and before the extraction of the sub-cores of operation 1 above. The success of this operation then prompted us to insert a 2x2 cm U-channel and the Portuguese to cut 8x5 cm ducting to perform the same operation. (see picture of a Box core with tubes in and side off).

Fig. 10. Box Cores showing (L) sampling of side with tray and U-channel and (R) tubes of various types and surface sampling guides. Clear plastic tube is pre-drilled to take Rhizons.

Fig. 11 Julia Gotschalk and Charlie Schoonman sample a box core.

Table 9. Box Core Log

Station	Core	Lat, N	Long, W	depth	length	remarks
				m	cm	
JC89-01	SHAK-01-1B	41° 00.00'	09° 28.50'	1299	9	after 2 failures, hard bottom. MORENA 'A'
JC89-02	SHAK-02-2B	41° 00.18'	09° 44.87'	2512	33	MORENA 'B'
JC89-03	SHAK-03-3B	37° 42.54'	10° 29.56'	3731	33-37	
JC89-06	SHAK-06-4B	37° 33.68'	10° 08.53'	2643	47	
JC89-07	SHAK-07-5B	30° 50.88'	10° 09.17'	3099	33-38	
JC89-08	SHAK-08-6B	37° 46.90'	10° 02.80'	2613	no record	will have to measure in sampled tubes
JC89-09	SHAK-09-7B	37° 49.82'	09° 49.32'	2323	no record	will have to measure in sampled tubes
JC89-10	SHAK-10-8B	37° 50.00'	09° 30.65'	1127	55	
JC89-11	SHAK-11-9B	37° 51.52'	09° 20.15'	617	30-32	
JC89-12	SHAK-12-10B	37° 59.36'	09° 35.41'	1607	47	
JC89-13	SHAK-13-11B	37° 56.12'	09° 35.11'	1442	55	
JC89-14	SHAK-14-12B	37° 50.16'	09° 43.16'	2063	40-46	
					Av max 43 cm	

Kasten Coring

We used the sideways-extruding system of Zangger & McCave (1990). Kasten cores were taken using the 1.45 tonne Piston corer core-head ('bomb') with an adaptor to take the square barrel. The intention was, wherever possible, to take 6 m cores made up of 4 m and 2 m barrels fish-plated together. Kasten performance was quite good with an average recovery of 4.33 m. Table 10 shows the locations, depths, recovery and comments for each of the 10 kasten cores taken during JC89.

The sub-sampling procedure was as follows:
Styrene trays (330 mm long x 150 mm wide x 25 mm thick) were taken along the length of kasten core. In some cores, a duplicate set was taken and offset to bridge the gap between adjacent trays.
U-channels (2x2 cm x 1.5m) were taken along the length of core.
Two subcores were taken with 8-cm x 6-cm electrical conduit.
Two subcores were taken with 5-cm square conduit.
Constant volume samples (10 cc) were taken with a syringe for water content and density.

With the recovery of SHAK-07-7K, we ran out of styrene trays and cut a D-tube to subsample the kasten core in lieu of trays.

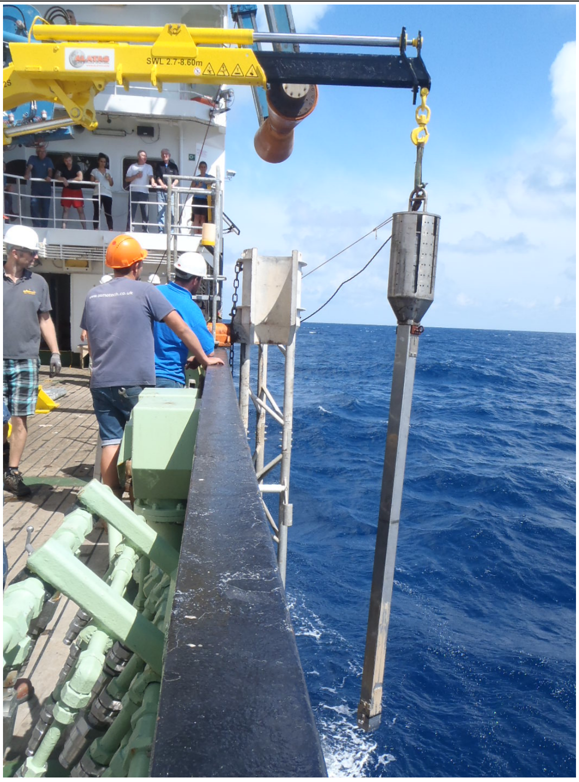


Fig. 12 Kasten core being recovered on JC089.

Fig. 13. Kasten core with lid removed prior to sampling.

Table 10. Kasten Cores

Station	Core	Lat, N	Long, W	depth m	length m	remarks
JC89-02	SHAK-02-1K	41° 00.17'	09° 44.87'	2514	1.48	4m barrel, wrong core catcher
JC89-04	SHAK-04-2K	37° 35.15'	10° 21.90	3477	3.25	6m barrel, wrong core catcher
JC89-05	SHAK-05-3K	37° 36.15'	10° 41.51'	4670	4.68	6m barrel
JC89-06	SHAK-06-4K	37° 33.68'	10° 08.53'	2646	4.75	6m barrel
JC89-06	SHAK-06-5K	37° 33.68'	10° 08.53'	2646	3.44	4m barrel. Whole core sliced at 1 cm by ETH crew
JC89-03*	SHAK-03-6K	37° 42.45'	10° 29.55'	3740	4.16	6m barrel
JC89-07	SHAK-07-7K	37° 50.88'	10° 09.17'	3100	4.24	6m barrel
JC89-08	SHAK-08-8K	37° 46.88'	10° 02.79'	2618	4.15	6m barrel
JC89-09	SHAK-09-9K	37° 49.82'	09° 49.32	2323	5.02	6m barrel
JC89-10	SHAK-10-10K	37° 50.00'	09° 30.65'	1127	4.18	6m barrel, MD2041 Site
* = reoccupation					Avge 4.33m for 6 m barrel with correct CC	

Piston Coring

On JC089 we used the well-tried NIOZ-type piston corer with 110 mm (i.d.) PVC- liner, but a few problems with the operation of the system were still encountered. The biggest of these problems was the fact that the corer always under-penetrated. This was essentially due to the fact that the 1.45 Tonne bomb weight was not large enough for the stiff sediment types being cored (with 3 barrel lengths total is 1.75 t). As there was no means of increasing the weight of the bomb we had to be content with little more than 10 m cores in 16 m effective barrel lenght. Although penetration was frequently to half-way up the top stand of pipe (13-14 m) the average recovery was 8.55 m. For future cruises, a 2.5 tonne bomb weight with removable 0.25 tonne weights would be recommended.

Table 11 shows the locations, depths, corer setup, recovery and comments for each of the 10 piston cores taken during JC89. These had a total length of ~80.5 m representing a modest degree of success.

The core liner was extruded from the barrel and cut into ~1.5-m sections. End caps were placed over the open ends and taped. A few cores were split onboard using an industrial router mounted to a metal frame. We are grateful to Russell Wynn (NOC) for its loan.

Table 11. Piston cores.

Station	Core	Lat, N	Long, W	depth	length	trigger	sect's	remarks
				m	m	m		All are 3 sects -'18m' EXCEPT 7P, 10P
JC89-03	SHAK-03-1P	37° 42.45'	10° 29.55'	3731	5.14	1.45	4	3.5 m freefall, 2 t total wt, 13.3 m penetration, poor recovery
JC89-04	SHAK-04-2P	37° 35.15'	10° 21.89'	3477	10.69		8	13.4 m penet^{n}
JC89-05	SHAK-05-3P	37° 36.26'	10° 41.50'	4670	7.45	0.45	6	13.2 m penet^{n}
JC89-07	SHAK-07-4P	37° 50.91'	10° 09.16'	3100	10.19		8	wind 28 knots
JC89-08	SHAK-08-5P	37° 46.90'	10° 03.80'	2619	9.20		7	
JC89-09	SHAK-09-6P	37° 49.28'	09° 49.28'	2323	9.02		6	
JC89-10	SHAK-10-7P	37° 50.00'	09° 30.65'	1127	8.08		6	3½ sect, '21m', ~ 13 m pen., no better recovery, 2 sects imploded
JC89-13	SHAK-13-8P	37° 56.12'	09° 35.12'	1413	7.95	0.70	7	
JC89-14	SHAK-14-9P	37° 50.16'	09° 43.61'	2063	9.28		7	
JC89-11*	SHAK-11-10P	37° 51.51'	09° 20.12'	618	3.43	0.18	3	2 sect/'12 m'; quite sandy
					Avge 8.55m for 3 sect '18 m' barrel			
* = reoccupation of site								trigger length records incomplete

Mega corer

The instrument used to obtain undisturbed samples of the sea bed was the Bowers Connelly Mega Corer ('mega corer' hereafter), manufactured by Ocean Scientific International Ltd (Culkin House, C7/C8 Endeavour Business Park, Penner Road, Havant, Hampshire PO9 1QN, U.K. ; osil@osil.co.uk). This replaces the older SMBA multicorer but works on the same principle of the hydraulically-damped descent of an array of core tubes in a lander frame. This system worked with >85% success. Successful tubes obtained 12 to 42 cm of sediment, averaging 30.0 cm. The megacorer was loaded with 8 tubes (100mm diameter x 600mm long) per deployment. In half of the positions (4) we mounted a pre-drilled tube for the insertion of Rhizones for pore-water sampling. The holes were taped over for deployment and opened up in the cold room for sampling. Table 12 shows the locations, depths, recovery for each tube and comments for each of the 13 deployments of the Megacorer during JC89.

Upon extraction from the frame, Mega Core tubes were immediately transferred to the temperature controlled room where the temperature of the overlying water and sediment recovery were recorded. Overlying water was filtered and sampled. Mega Core tubes with predrilled holes were extracted for pore water using Rhizones (see Section 7.3). The remaining tubes were taken to extrusion tables with a 1-cm ratchet extruder to give precise slices which were then bagged (Figures 15 & 16).

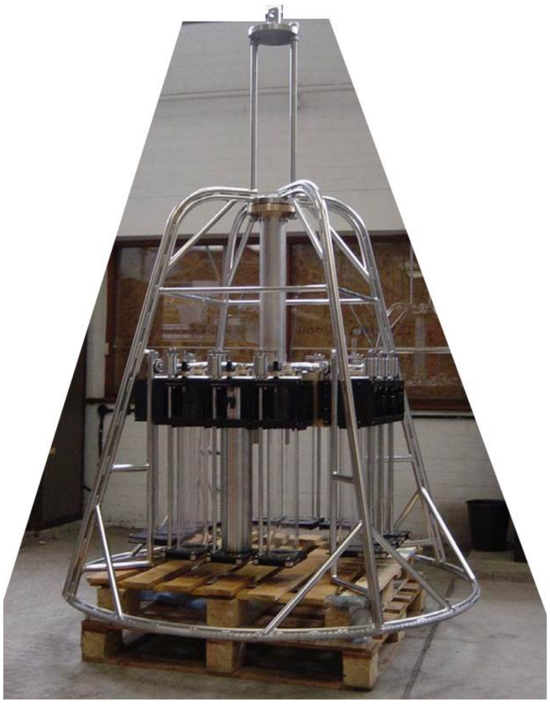


Fig. 14. The OSIL Mega Multiple Corer.

Table 12. Mega Cores

Mega Cores

Station	Core	Lat, N	Long, W	Depth m	A	B	C	D	E	F	G	H	Failed Tubes	Comments
JC89-02	SHAK-02-1M	41° 00.18'	09° 44.87'	2512		12.0	11.5	10.5		10.1		17.9	A	Tube 'E' bagged whole.
JC89-03	SHAK-03-2M	37° 42.34'	10° 29.52'	3729	22.0	26.0	26.0	27.0	13.0	13.0	26.0	27.0		
JC89-04	SHAK-04-3M	37° 35.15'	10° 21.89'	3495	28.0	29.0	31.0	31.0	20.5	17.5	32.0	29.0		
JC89-05	SHAK-05-4M	37° 36.26'	10° 41.51'	4672	40.0	38.0		37.0	12.3	31.0	35.0		C,H?.	H is listed for ETH Zurich
JC89-06	SHAK-06-5M	37° 33.68'	10° 08.53'	2645	28.0	29.0	30.0	28.0	25.0	30.0	30.0	26.0		
JC89-07	SHAK-07-6M	37° 50.91'	10° 09.16'	3100	26.0	27.0	29.0	26.0	23.0	27.0	26.0	24.0		wind force 6 (23kt), working well
JC89-08	SHAK-08-7M	37° 46.90'	10° 02.80'	2619	31.0	29.0	31.0	31.0	18.0	28.0	31.0	30.0		
JC89-09	SHAK-09-8M	37° 49.83'	09° 49.30'	2323	40.3	38.5	39.8		34.0	34.4	40.5	39.4	D.	
JC89-10	SHAK-10-9M	37° 50.50'	09° 30.65'	1127		39.0	41.0	45.0		13.0	50.0	42.0	A,E.	
JC89-11	SHAK-11-10M	37° 51.51'	09° 20.15'	628		14.0	22.0	24.0	16.0	23.0		22.0	A,G?.	G is listed for ETH Zurich
JC89-12	SHAK-12-11M	37° 58.35'	09° 35.91'	1611	39.5	42.0	41.0		34.0	40.5	38.0		D,H.	
JC89-13	SHAK-13-12M	37° 56.12'	09° 35.10'	1448	6.5	41.0	42.0		34.0	40.0	38.0		D,H.	
JC89-14	SHAK-14-13M	37° 50.16'	09° 43.61'	2062	38.5	40.0	42.0	39.5	41.5	41.5	42.0	39.5		
					30.0	**31.1**	**32.2**	**29.9**	**24.7**	**26.8**	**35.3**	**29.7**	avge (30.0)	
					11	14	13	11	12	14	12	11	n	

Fig. 15. Purpose-built table for extruding and sampling megacore tubes. Designed and fabricated at the University of Cambridge.

Fig. 16. Sampling of a Megacore tube using the Cambridge extruding and sampling table.

Gravity corer

Four gravity cores were taken at stations 11 to 14 using the piston core head with a single '6 m' length of lined core barrel. This was very successful and an average length of 5.1 m was recovered. The shortest core was 4.58 m at a water depth of 618 m on the upper slope where the bed was more sandy. Table 13 shows the locations, depths, recovery and comments for each of the 4 gravity cores taken during JC89. Gravity cores were extruded from the barrel and cut into 1.5-m sections. Some gravity cores were split aboard ship.

Table 13. Gravity cores.

Station	Core	Lat, N	Long, W	depth	length	remarks
				m	m	
JC89-11	SHAK-11-1G	37° 51.51'	09° 20.14'	618	4.58	Top 20 cm dropped post-cutting. Some disturbance.
JC89-12	SHAK-12-2G	37° 59.36'	09° 35.91'	1600	5.35	Top 10cm dropped.
JC89-13	SHAK-13-3G	37° 56.12'	09° 35.10'	1440	5.19	
JC89-14	SHAK-14-4G	37° 50.16'	09° 43.16'	2063	5.13	
					5.06 m avge length	

Grab

At the last station in 400 m of water we deployed the Day Grab for a surface sample (Table 14). Despite it being fouled it had closed and a small sample was retrieved. This operation is made almost impossible due to having to deploy on the heavy core wire of ~13 mm diameter instead of the usual (but no longer available) 4 mm hydrowire.

Table 14. Grab sample.

Grab sample					
JC89-15	SHAK-15-1Gr	37° 49.38'	09° 11.00'	405	A few spoons full, but enough

References
Hessler, R.R. & Jumars, P.A. 1974. Abyssal community analysis from replicate box cores in the central North Pacific. *Deep-Sea Res*., **21**, 185-209.
Zangger E. and McCave, I.N. 1990. A redesigned Kasten core barrel and sampling technique. *Marine Geology*, **94**: 165-171.
OSIL Ltd, *Overview of OSIL Mega Multiple Corer*, Ocean Scientific International Ltd, Havant, Hampshire, UK, 19 pp (unpublished). (http://www.osil.co.uk/).

7.3 Pore-water chemistry

7.3.1 Personnel:

Box-cores, multi-cores and piston cores were collected by the shipboard coring team (see section 7.2).
Porewaters were extracted and processed by:

Harry Elderfield - University of Cambridge (harrye@esc.cam.ac.uk)
Mervyn Greaves - University of Cambridge (mg109@cam.ac.uk)
Anna-Lena Grauel - University of Cambridge
Maria de la Fuente - Institut de Ciències del Mar, CSIC, Barcelona, Spain
Duygu Sevilgen - Max Planck Institute, Bremen, Germany (dssevilg@mpi-bremen.de)

7.3.2 Rationale

The ability to infer past climate change is inextricably linked to proxy development and empirical calibration of proxies with modern observations. However, there is a lack of studies examining in detail the relationships of multiple geochemical proxies in benthic foraminifera to the chemistry of the sediments and associated pore waters. For example, accurate calibrations of benthic foraminiferal ‘Mg/Ca thermometry’ require core tops that span a range of hydrographic conditions along a local depth transect and, in order to obtain deep-water temperature reconstructions across glacial and interglacial time periods, infaunal as well as epifaunal benthic foraminifera must be used. We need to establish whether the geochemical signature of a given foraminifera species reflects a bottom water signal, a pore-water signal or some combination of these. The careful study of pore-water chemistry is required, in conjunction with pristine modern core-top sediment and the geochemistry and vertical distribution of associated benthic foraminifera.

7.3.3 Objectives

The primary objective of the geochemistry program is to utilise water column, sediment and pore-water analyses to test the underlying rationale and calibration of key trace-element and isotope proxies. This will include an assessment of early diagenetic influences on the chemistry of infaunal versus epifaunal benthic foraminifera, and will target proxies for temperature (Mg/Ca), carbonate chemistry (e.g., B/Ca), nutrient concentrations (e.g., $\delta^{13}C$, Cd/Ca) and redox state (U, Mo, Mn, V, Fe). A key goal will be to combine these proxies to interpret the down-core record of millennial–scale climate variability for the last glacial cycles.

7.3.4 Sampling methodology

The Bowers Connelly Mega Corer (manufactured under license by OSIL) was used to collect multi-cores for pore water chemistry analyses at each site, with emphasis on high-resolution (cm-scale) pore fluid geochemistry in the upper metre of sediment. Multi-cores were transferred immediately from the work deck to the climate controlled laboratory for processing at near bottom water temperatures (4 +/-2 ^{o}C). At each site, one muti-core was used for the on board determination of pore-water oxygen gradients by Duygu Sevilgen, using micro-electrodes. Interstitial waters were extracted from up to three multi-cores, using Rhizon samplers (Rhizosphere Research Products, http://www.rhizosphere.com/) spaced at 1cm intervals through sealed ports in the multicores [Seeberg-Elverfeldt et al., 2005]. Rhizon sampling followed a modification of the method used by Homoky *et al* on Cruise JC068. Mega-core tubes were pre-drilled at 1cm intervals to permit insertion of 50 mm long, 2.5 mm wide, 0.15 µm membrane Rhizon samplers, drill holes being sealed with PVC tape prior to deployment of the Mega Corer (Fig. 17). Rhizons and syringes were acid cleaned prior to the cruise using 3M HCl followed by 1.5M HNO_3 and an overnight soak in high purity deionised water. The syringes were filled with Milli-Q water and Rhizons rinsed again immediately before use in the climate controlled laboratory. Cores to be sampled were kept upright in secure racking, the insulation tape perforated using a clean stainless steel blade and Rhizons inserted. Pore-water was extracted by withdrawing the syringe plungers and holding fully extended using wooden blocks, taking approximately two hours for each core tube.

Pore waters were extracted from sub-cores of box cores at two sites and from piston cores collected at six sites. Piston cores were sampled using Rhizon samplers spaced at 20 cm intervals, with the core tube sections held horizontally and holes drilled for insertion of Rhizons as required in the climate controlled laboratory (Fig 18). Rhizons and fitted syringes were left overnight to extract porewaters from the piston core sections. Samples collected from piston cores were filtered additionally through syringe filters (Whatman Autotop WF). Cores sampled are listed in Table 15.

Table 15. Cores sampled for porewater

Station	Core	Subcore
	Multi-cores	
JC089 SHAK-02	1M	C, F
JC089 SHAK-03	2M	A, C

JC089 SHAK-04	3M	A, C, H
JC089 SHAK-05	4M	B, G
JC089 SHAK-06	5M	B, F, H
JC089 SHAK-07	6M	C, F
JC089 SHAK-08	7M	B, D, H
JC089 SHAK-09	8M	B, H
JC089 SHAK-10	9M	C, H
JC089 SHAK-11	10M	D, F
	Piston cores	
JC089 SHAK-05	3P	
JC089 SHAK-07	4P	
JC089 SHAK-08	5P	
JC089 SHAK-09	6P	
JC089 SHAK-10	7P	
JC089 SHAK-13	8P	
	Box cores	
JC089 SHAK-02	2B	
JC089 SHAK-03	3B	

Alkalinity measurements were made onboard ship from all porewater samples. Pore water fluid samples were preserved for shore-based analyses of $\delta^{13}C$, $\delta^{18}O$, dissolved inorganic carbon (DIC), phosphate, silicate and trace metals from the multi-cores depending on sample volume available. Sampling details and preservation methods are shown in Table 16 below.

Table 16. Porewater samples and preservation taken aboard JC089.

Sample	Vial	preservation
Alkalinity	2ml Picarro vial	measured on-board
$\delta^{13}C$	2ml heat sealed ampoule	10ul $HgCl_2$ added
DIC	5ml heat sealed ampoule	Flushed with N_2 & 10ul $HgCl_2$ added
Trace metal	15ml Nalgene LDPE bottle	20ul HNO_3 added
$\delta^{18}O$	2ml Picarro vial	none
PO4	2ml Picarro vial	frozen on-board
Si	15ml Nalgene bottle	none

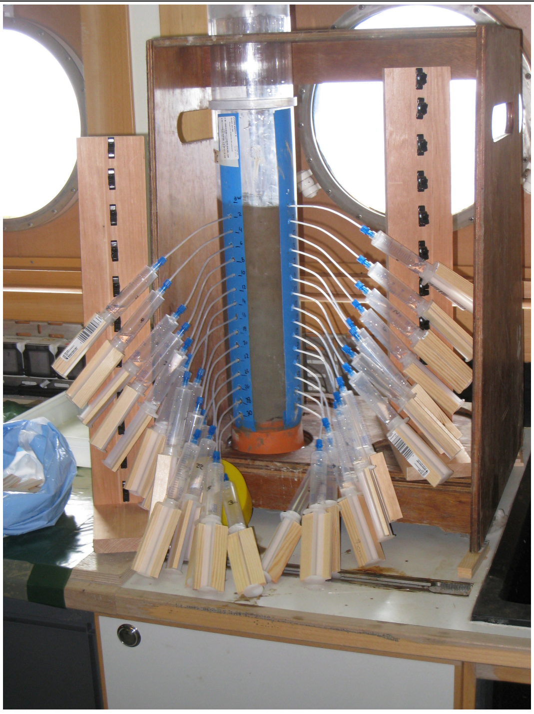


Fig. 17. Pore water extraction from a megacore using Rhizon samplers. Blue tape sealed the holes during deployment and recovery of the Mega Cores.

Fig. 18. Anna-Lena Grauel and Maria de la Fuente fitting Rhizon samplers to sections from a Piston Core

7.3.5 Shipboard measurements (alkalinity, microelectrodes)

7.3.5.1 Alkalinity measurement

Harry Elderfield, Mervyn Greaves, Anna-Lena Grauel, Maria de la Fuente.

Porewater alkalinity was determined by titration using a Metrohm Titrino with 5ml burette and stirrer plate, following methods used previously (R.A. Mills and R.H. James, *pers. comm.*) based on the method of Bruevich as described by Pavlova *et al* (2008). Porewater samples were diluted 10 fold with Milli-Q water (500 ml porewater plus 4.5 ml Milli-Q) and titrated with 0.0005 M HCl while bubbling with N_2 to remove evolved CO_2 from solution. A mixed Methyl Red/Methylene Blue indicator was used to determine the endpoint, indicated by a stable salmon pink colour. The 0.0005 M HCl solution was standardised by titration against 0.001 M Na_2CO_3 solution, itself prepared from pre-weighed sodium carbonate powder. Accuracy of the alkalinity titrations was verified by titration with IAPSO standard seawater.

Fig. 19. Titration of pore-water samples for the determination of alkalinity

Preliminary results from shipboard alkalinity determinations showed alkalinity increasing downcore with significant differences between stations, evident in multi-cores and becoming more pronounced in the longer piston cores.

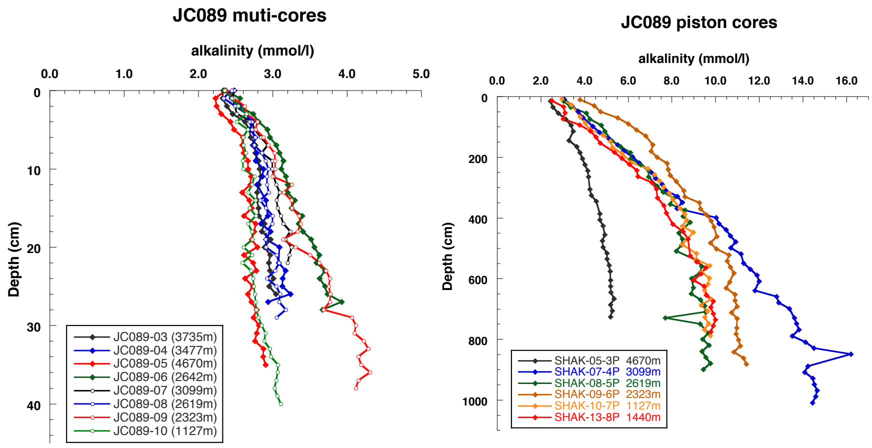


Fig. 20. Pore-water alkalinity profiles in multi-cores and piston cores

7.3.5.2 Microsensor measurements

Duygu Sevilgen (dssevilg@mpi-bremen.de)

Microprofile measurements were made to determine the distribution of oxygen and pH within the sediment pore-waters. Microsensor profiles of oxygen, pH and redox-potential were measured in multiple mega-cores at several stations throughout cruise JC089 by Duygu Sevgi Sevilgen (Table 17). Due to instrument failure/damage, measurements for the redox-potential were unsuccessful. Appendix XVII contains the original measuring data, the corresponding calibrations and profiles.

Table 17. Microelectrode measurements of oxygen and pH made on Multicores (*M*) or sub-cores from the Box-corer (*B*) during JC089.

Oxygen:

Core (SHAK-site-#core-subcore)	Date	Number of Profiles
SHAK-02-1M-H	06.08.2013	3
SHAK-03-2M-G	07.08.2013	3
SHAK-04-3M-F	12.08.2013	6
SHAK-05-4M-E	17.8.2013	3
SHAK-06-5M-C	17.08.2013	3
SHAK-07-6M-D	19.08.2013	4
SHAK-08-7M-E	20.08.2013	5
SHAK-09-8M-F	21.08.2013	4
SHAK-10-09B	22.08.2013	6
SHAK-11-10M-E	23.08.2013	3
SHAK-12-11M-G	23.08.2013	5
SHAK-13-12M-C	23.08.2013	4

SHAK-14-13M-D	23./24.08.2013	3

pH:

Core (SHAK-site-#core-subcore)	Date	Number of Profiles
SHAK-08-6B	20.08.2013	2
SHAK-09-7B	20.08.2013	1
SHAK-10-8B	21.08.2013	2
SHAK-11-9B	22.08.2013	1
SHAK-12-10B	23.08.2013	1
SHAK-14-12B	24.08.2013	2

Calibration & Measurement information

Cores were stored in a temperature controlled room and transferred to an isothermal water-bath at near bottom water temperatures during measurements (see data sheets for further details).

pH

The pH meter was calibrated onboard using commercially available buffer solutions Mettler Toledo, pH 4.01, pH 7.00, pH 9.21]

Profiles were measured twice, both down and up, starting in the overlying water and continuing with depth in the sediment, followed by reversing the process.

Oxygen

Measurements were calibrated using oxygen solubility at the measured salinities (37PSU) and temperature according to the Unisense Gas tables (Li & Gregory 1974, Garcia & Gordon 1992) (http://www.unisense.com/files/PDF/Diverse/Seawater%20&%20Gases%20table.pdf)

Two-point linear calibration was done with oxygen values from the overlaying water (assuming saturation upon bubbling with air) and in the anoxic part of the sediment (or in N_2 aerated seawater at the same temperature).

Zero cm was taken to be the approximate position of the sediment surface (anything above is in the overlying water, anything below in the sediment) and oxygen concentrations are given in [$\mu mol\ l^{-1}$]

Measurements and post-cruise processing

Data were generated using the software by m-Profiler server v3.01 (http://www.mpi-bremen.de/~lpolerec/micro-profiler/).

Transformation of the measuring signal to oxygen concentrations and pH-values as well as processing of the profiles (adjusting the sediment surface and deleting outliers) was done on board and after the cruise using EXCEL. More detailed information is given in the "Overview"-worksheets as well as in the single worksheets of the EXCEL-data-files.

Figure 18 shows a compilation of the oxygen profiles showing oxygen depletion occurs at most stations within the upper 5 cm.

Problems encountered

pH profiles measured prior to SHAK 08 were not successful due to electrical noise disturbing the mV-meter signal in the Chemistry lab. After several days of trouble-shooting the instrumentation for pH measurements was moved to the Main-Lab where pH profiles were measured manually in sub-cores of the Box-corer.

Similarly, redox-profiles were disturbed and unsuccessful. Due to the failure and breaking of all redox-sensors that were available (5 sensors), no redox-profiles could be measured after moving the set-up.

Processed data are compiled in the EXCEL data files: Oxygen_JC089 and pH_JC089 (Appendix XVII).

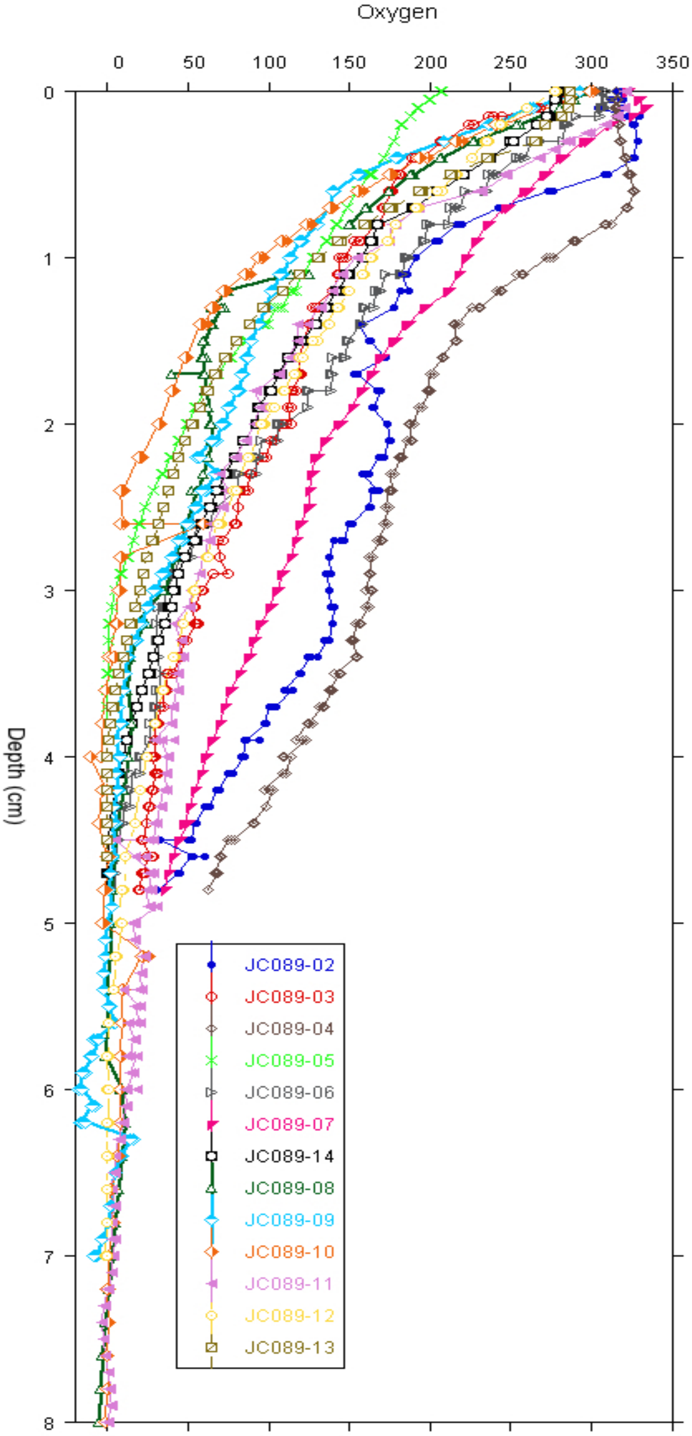


Fig. 18. Selected oxygen profiles at each station showing oxygen depletion at most stations within the upper 5 cm.

7.3.6 *Post cruise samples analyses*

Preserved pore-water samples were returned to Cambridge for post cruise analyses. DIC to be determined at the carbonate chemistry facility at the National Oceanography Centre, Southampton. Porewater samples to be analysed for $\delta^{13}C$, $\delta^{18}O$, phosphate and trace metals in the Godwin Laboratory for Palaeoclimate Research at the University of Cambridge. Silicate and silicon isotope determinations will be made by Kate Hendry at the University of Bristol.

Acknowledgments

We sincerely thank Rachel Mills, Rachael James, Matthew Cooper and Will Homoky for their advice on porewater sampling using Rhizons, on the shipboard determination of alkalinity from extracted porewater samples, and for the generous loan of the associated equipment.

References

Garcia, H. E. and Gordon, L.I., 1992. Oxygen solubility in seawater- better fitting equations. Limnol. Oceanogr. 37, 1307-1312.

Homoky et al. 2012, RRS James Cook cruise report JC068, Workpackage 3, sediment fluxes p 39-49

Li, Y.H. and Gregory, S., 1974. Diffusion of ions in sea-water and in deep-sea sediments. Geochimica Et Cosmochimica Acta 38, 703-714.

Pavlova et al . 2008, Intercalibration of Bruevich's method to determine the total alkalinity in seawater. Oceanology, 48, 438 – 443

Seeberg-Elverfeldt et al., 2005. Limnol. Oceanogr., Methods 3, 361–371

7.4 Foraminifer Staining

Natalia Vázquez Riveiros (Natalia.Vazquez@lsce.ipsl.fr)
Now at:
Laboratoire des Sciences du Climat et de l'Environnement (CNRS, Gif-sur-Yvette, France)

Multicores at selected stations were sampled and stained with Rose Bengal and Cell Tracker Green to distinguish between living and dead foraminifera (Bernhard et al., 2006).

Rose Bengal Protocol
- A solution of rose Bengal stain was prepared using 1 g of stain to 1 L of 80% ethanol.

- One of the MegaCore was extruded and the upper ~ 10-15 centimeters* sampled at 1-cm intervals for staining. Samples had a volume of ~ 80 cm^3.
- Each sample was placed in a 250 mL Nalgene bottle (wide mouth), and an equal volume of staining solution was added to the sample. The sample was shaken gently to ensure homogeneous mixing of stain and sediment.
- Samples were preserved in Nalgene bottles with proper labels for postcruise processing.

* Normally, sampling the first 10-cm of sediment will be sufficient to capture all living forams. The decision to sample deeper than 10 cm was made after checking the microelectrode oxygen profiles (Figure 16).

CellTracker Green (CTG) Protocol

A 1.5 mL solution of 10 mM CellTracker Green (CTG) was prepared by dissolving 5 mg of CTG in 1 mL of dimethyl sulfoxide (DMSO). The solution was kept frozen until use.
- One of the MegaCore was extruded and the upper ~ 10-15 centimeters* sampled at 1-cm intervals for staining.
- Each sample was placed in a 500 mL Nalgene bottle, and covered with an approximately equal volume (~ 100 mL) of local bottom water maintained at ambient temperature. Water and sediment were agitated to promote mixing.
- 10 microliters of 10 mM CTG + DMSO solution was added to the bottles (the final concentration of CTG in seawater should be 1 μM). The CTG solution was kept frozen until the moment of injection. The samples were incubated with the staining solution at seabed temperatures for at least 8 hours to allow the foraminifera to incorporate CTG and produce the fluorescent compound.
- Following incubation, volume of preservative solution (70% ethanol) equal to the volume of the sample (approximately 160 to 200 mL) was added.
- The samples were stored in Nalgene bottles with the staining solution and preservative.

Bernhard, J. M., D. R. Ostermann, D. S. Williams, and J. K. Blanks (2006), Comparison of two methods to identify live benthic foraminifera: A test between Rose Bengal and CellTracker Green with implications for stable isotope paleoreconstructions, Paleoceanography, 21, PA4210, doi:10.1029/2006PA001290.

7.5 CTD water sampling

7.5.1 Personnel

Alex Thomas
Grant Institute, The King's Buildings, West Mains Road, Edinburgh EH9 3JW
alex.thomas@ed.ac.uk

Catarina Cavaleiro
Instituto Português do Mar e da Atmosfera,
Divisão de Geologia e Georecursos Marinhos,
Estrada da Portela, Zambujal, Apartado 7586, 2721-866 Alfragide, Portugal

John Wynar, NMF CTD technician (jbwy@noc.ac.uk)

7.5.2 CTD instrumentation and calibration

In total, 13 CTD casts made using during JC089 with a trace metal free system (Table 17). The Station number and SHAK number are all coincident, however the cast numbers are all offset by -1 due to their being no CTD cast at the sation1 (SHAK#1). Throughout this report the CTD casts are numbered according to the cast# and not the station or SHAK# to maintain consistency with the datafiles generated by the CTD system.

The CTD sensor information is given in Table 18. The pressure sensor was located 33cm below the bottom and approximately 70cm below the centre of the 10L water sampling bottles. The configuration file used for all casts was JC089_0637_ti.xmlcon.

CTD wire 1 was used throughout, only once being terminated at the start of the cruise. In an attempt to prevent the wire from "un-wrapping", the wire was streamed twice, first to 3000m and then later during the cruise to 4600m depth. On each occasion a 600kg weight with a swivel attached was used.

Table 17. CTD Deployments

Lat N	Long E	Station	SHAK#	Cast#	Event#	Depth m
41.00283	-9.74800	2	2	1	4	2503
37.70867	-10.49250	3	3	2	12	3710
37.57967	-10.35800	4	4	3	15	3465
37.61117	-10.69167	5	5	4	21	4617
37.55700	-10.13783	6	6	5	26	2616
37.84783	-10.15267	7	7	6	32	3093
37.79517	-10.04650	8	8	7	38	2629
37.83317	-9.81817	9	9	8	45	2317
37.83333	-9.51083	10	10	9	51	1130
37.85833	-9.33533	11	11	10	57	619
37.98883	-9.59833	12	12	11	61	1605
37.93517	-9.58500	13	13	12	66	1439
37.83550	-9.72683	14	14	13	71	2059

Table 18. Sensor information for the titanium CTD main frame used during JC089

SHIP: RRS JAMES COOK	CRUISE: JC089

FORWARDING INSTRUCTIONS / ADDITIONAL INFORMATION:
AS BUILT ON BOARD DURING JC088 FOR JC089 Titanium CTD (Main frame for JC089)

Checked By: J Wynar	DATE: 26 July 2013

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-24680-0587	n/a	Primary CTD deck unit
Secondary CTD deck unit	SBE 11plus	11P-19817-0495	n/a	Secondary CTD deck unit
CTD Underwater Unit	SBE 9plus	09P-24680-0637T	n/a	n/a
Titanium 24-way frame	NOCS	SBE CTD TITA2	n/a	n/a
Digiquartz Pressure sensor	Paroscientific	79501	F3	n/a
Primary Temperature Sensor	SBE 3P	3P-5494T	F1	n/a
Secondary Temperature Sensor	SBE 3P	3P-5495T	F4	n/a
Primary Conductivity Sensor	SBE 4C	4C-3874T	F2	n/a
Secondary Conductivity Sensor	SBE 4C	4C-3567 T	F5	n/a
24-way Carousel	SBE 32	32-60380-0805T	n/a	n/a
Primary Pump	SBE 5T	5T-4510	n/a	n/a
Secondary Pump	SBE 5T	5T-4539	n/a	n/a
Dissolved Oxygen Sensor	SBE 43	43-0709	V0	n/a
Free			V1	n/a
Altimeter ***On Direct Cable to 9+, no Y Cable fitted.***	Benthos	47597	V2	n/a
Free			V3	n/a
Free			V4	n/a
BBRTD Light Scatter Sensor	Wetlabs	**BBRTD758R**	V5	n/a
Transmissometer	CTG Alphatracka	161048	V6	n/a
Fluorimeter	CTG Aquatracka MKlll	088244	V7	n/a
LADCP battery pack (Titanium)	NOCS	WH008T	n/a	n/a
10L TMF Water Samplers	OTE	. 1 through 29	n/a	n/a
LADCP (Titanium) ***Firmware updated from 50.38 to 50.40 during JC088***	TRDI WHM 300kHz	10607	n/a	n/a

Post-processing the CTD cast data was basically to guidelines established with BODC (ref. Moncoiffe 7th July 2010), but as the sea was relatively calm during casts the Loop

Edit and Wild Edit routines were not used.

A Guildline Autosal 8400B salinometer, s/n: 60839, was used for salinity measurements. The salinometer was set up in the Electronics Workshop, with the bath temperature set at 21°C, the ambient temperature being approximately 19°C. A bespoke program written in Labview called “Autosal” was used as the data recording program for salinity values.

The salinometer was standardized at the beginning of the first set of samples, and checked with an additional standard analysed prior to setting the RS. Once standardized the Autosal was not adjusted for the duration of sampling. Additional standards were analysed every 24 samples to monitor & record drift. These were labelled sequentially, beginning with number 999 and thereafter decreasing. Standard deviation set to 0.00002

Salinity samples were taken and analysed from casts 1 to 5 inclusive, and casts 7 and 8, the results being tabulated in a spreadsheet JC89_SAL.XLS. When these results are compared with the Seabird 9plus sensors, it can be seen that the final measurement is anomalous. This may be due to contamination from either the water sampler bottles not sealing or poor sampling protocols, or errors made during the analysis. If this outrider is removed the resulting table (JC89_SAL_1.xlsx) gives a better summary of the performance of the conductivity sensors. From this it can be seen that the average primary error is -0.00068 but the average secondary error is 0.00173.

7.5.3 Hydrography

Subsurface water masses are recognized by their T-S characteristics (Figures 19 & 20). Eastern North Atlantic Central Water (ENACW) occupies the depth interval below the thermocline between ~50 and 500 m (van Aken, 2001). Between 500 and 1500 m, the warm, salty Mediterranean Overflow Water (MOW) dominates. MOW forms in the Gulf of Cadiz and splits into two cores centered at ~800 and 1200 m (Ambar and Howe, 1979), flowing north along the western Iberian margin. MOW sheds many eddies, termed meddies, that have been recognized by seismic oceanography (Pinheiro et al., 2010). Below 2000m, recirculated Northeast Atlantic Deep Water (NEADW) prevails, representing a mixture of Labrador Sea Water (LSW), Iceland Scotland Overflow Water (ISOW), Denmark Strait Overflow Water (DSOW), and to a lesser extent of MOW and Lower Deep Water (LDW) (van Aken, 2000). The deepest water mass is southern-sourced Lower Deep Water (LDW) which was only encountered at the deepest station below 4,000 m (van Aken, 2000).

Ambar, I., Howe, M.R., 1979. Observations of the Mediterranean Outflow: 1. Mixing in the Mediterranean Outflow. Deep-Sea Research Part A 26 (5), 535-554.

Pinheiro, L.M., Song, H., Ruddick, B., Dubert, J., Ambar, I., Mustafa, K., and Bezerra, R., 2010. Detailed 2-D imaging of the Mediterranean outflow and meddies off W Iberia from multichannel seismic data. Journal of Marine Systems 79, 89–100.

van Aken, H.M., 2000. The hydrography of the mid-latitude Northeast Atlantic Ocean – Part I: The deep water masses. Deep-Sea Research Part I 47, 757-788.

van Aken, H.M., 2001. The hydrography of the mid-latitude Northeast Atlantic Ocean – Part III: the subducted thermocline water mass. Deep-Sea Research Part I: Oceanographic Research Papers 48 (1), 237-267.

7.5.4 Water collection

Water samples were collected from the titanium rosette, which was fitted with trace metal clean 10L OTE (Ocean Technology Equipment) sampling bottles with external springs, modified for trace metal work. The OTE sample bottles were then transferred to a dedicated chemistry van on the back deck for sample processing. The titanium rosette was deployed on a steel cable. Bottle taps were covered with PVC gloves as soon as the package landed on deck, and prior to deployment, to minimise contamination.

The OTE bottles were fired on the up cast using the temperature, salinity, oxygen, and transmissiometry sensor traces as a guide for suitable sampling depths. The strategy was to sample close to the bottom (using the altimeter as a guide), with coverage of the whole water column but with higher density sampling towards the bottom and ensuring all of the near surface features are characterised.

Figures 21 to 33 show the locations of the discreet samples from each cast. Note that the profiles are listed by cast# and NOT station or SHAK#.

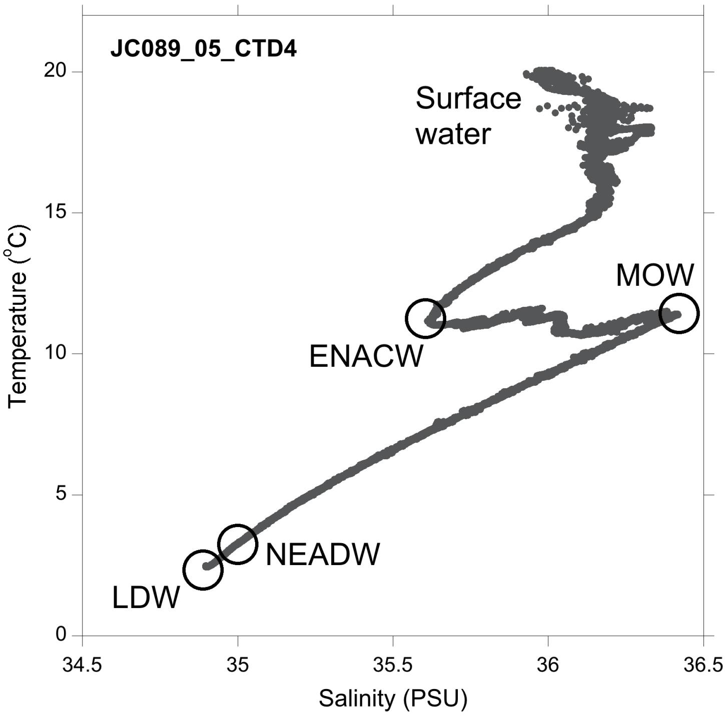


Fig. 19. Temperature-Salinity plot from SHAK-5 at 4670 m water depth showing major water masses. LDW= Lower Deep Water; NEADW = Northeast Atlantic Deep Water; MOW= Mediterranean Outflow Water; ENACW = Eastern North Atlantic Central Water

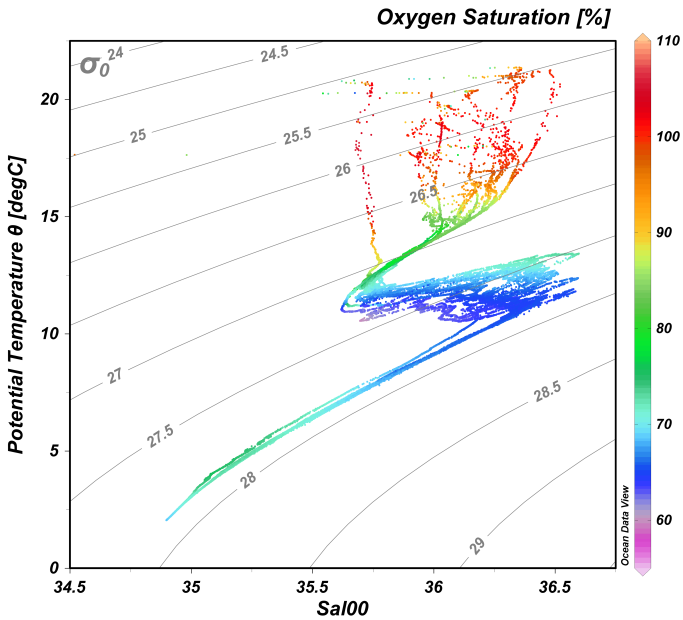


Figure 20. Composite T-S plot for all CTD casts. Contours are potential density. Colour shows the oxygen saturation of the water.

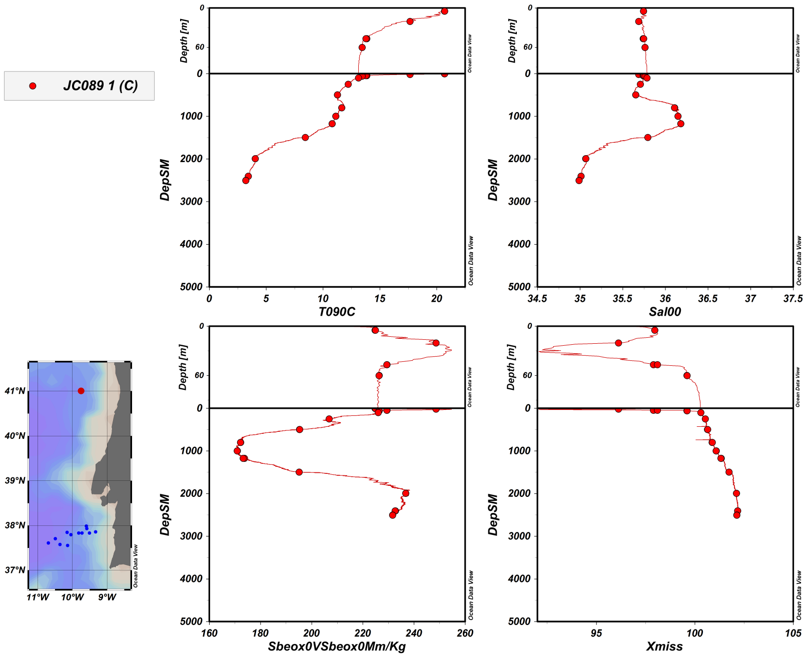


Figure 21. Profiles for cast 1 at Station JC089-02. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map.

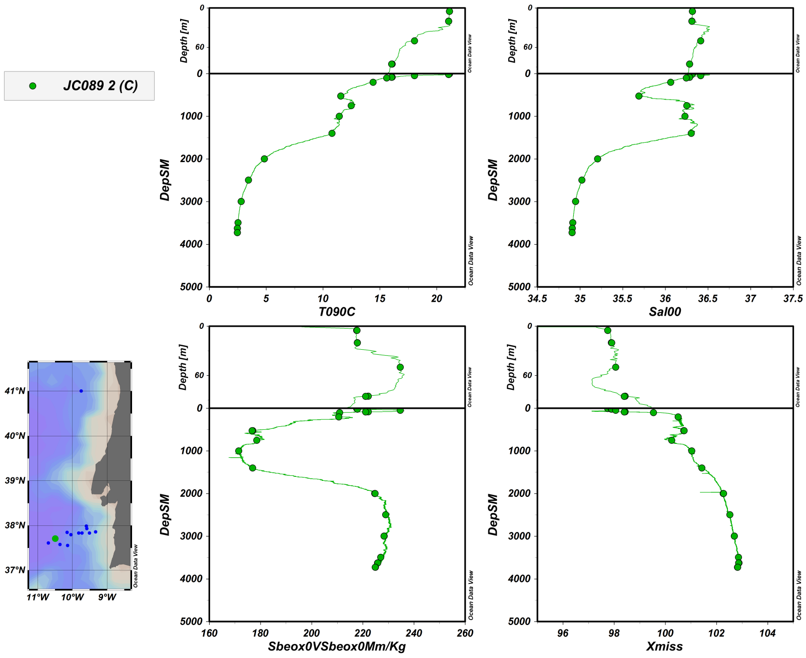


Figure 22. Profiles for cast 2 at Station JC089-03. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map

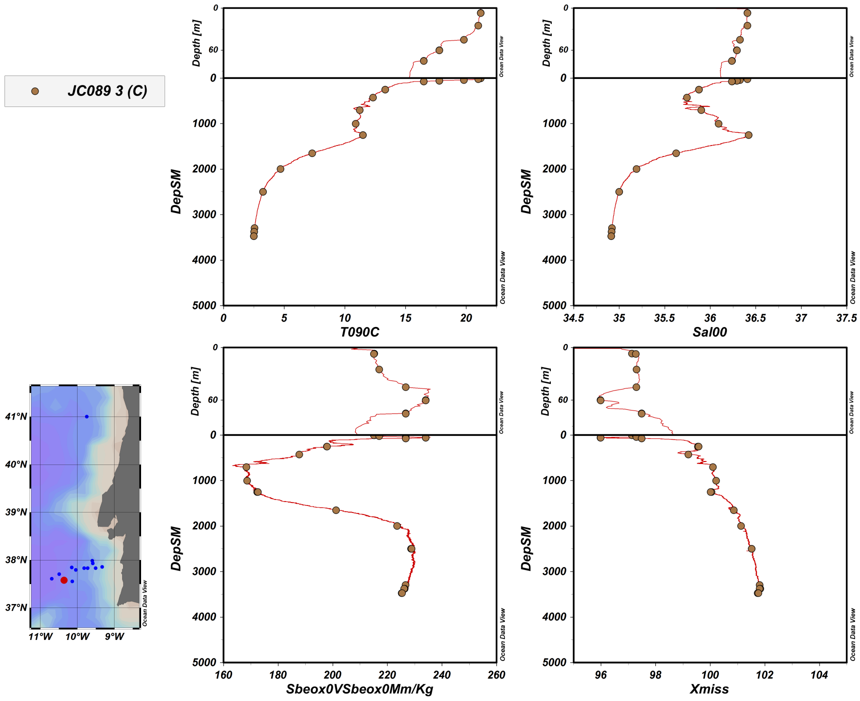


Figure 23. Profiles for cast 3 at Station JC089-4. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map.

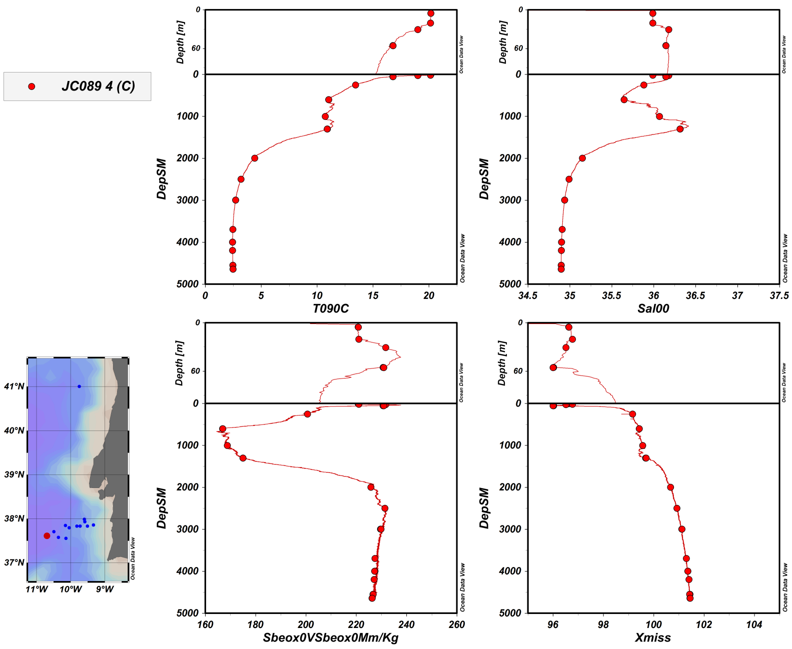


Figure 24. Profiles for cast 4 at Station JC089-5. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map

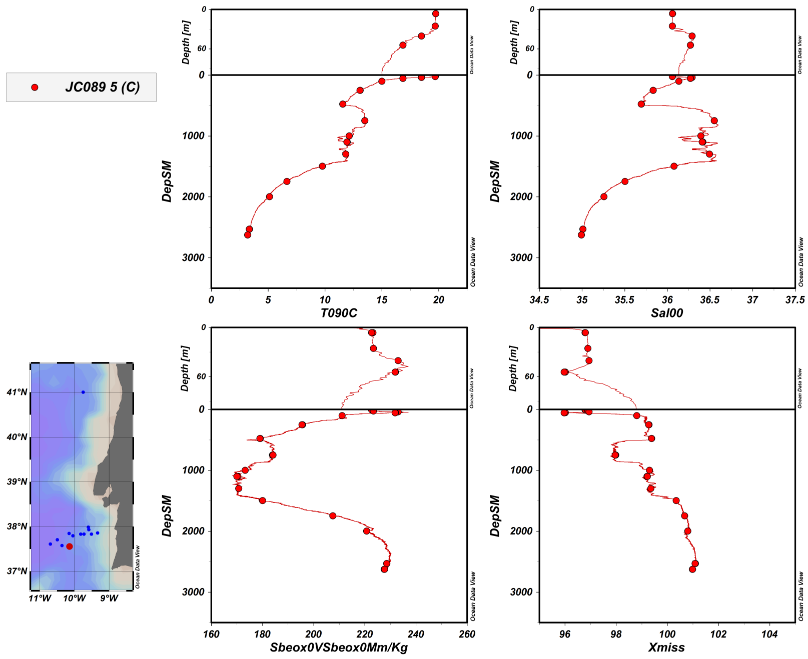


Figure 25. Profiles for cast 5 at Station JC089-06. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map.

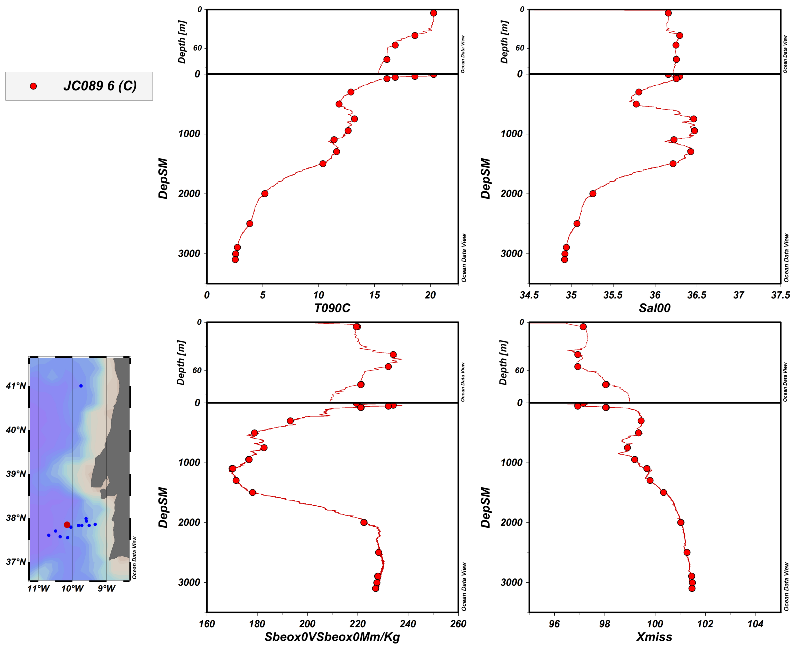


Figure 26. Profiles for cast 6 at Station JC089-07. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map

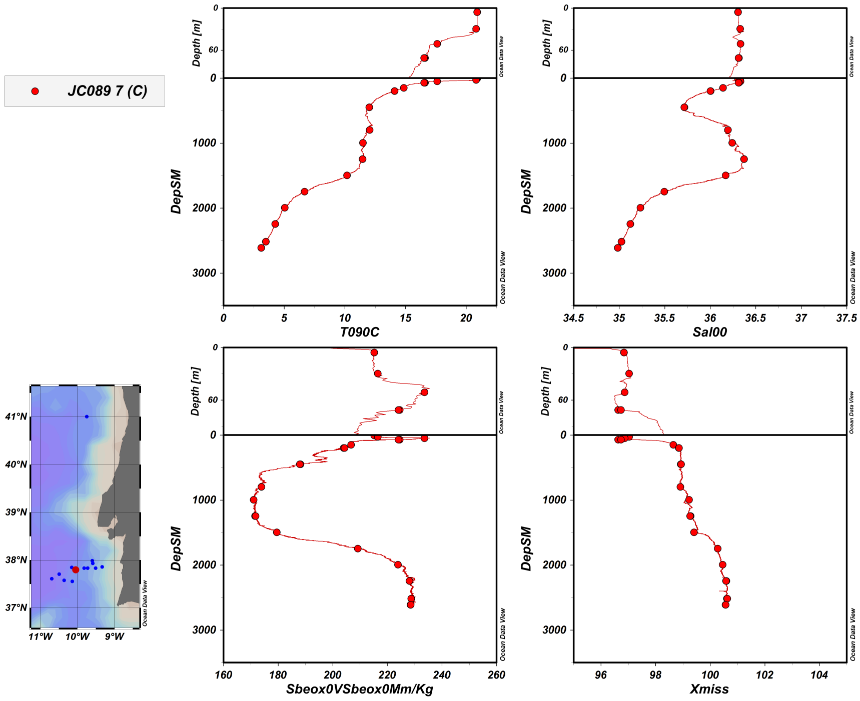


Figure 27. Profiles for cast 7 at Station JC089-08. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map

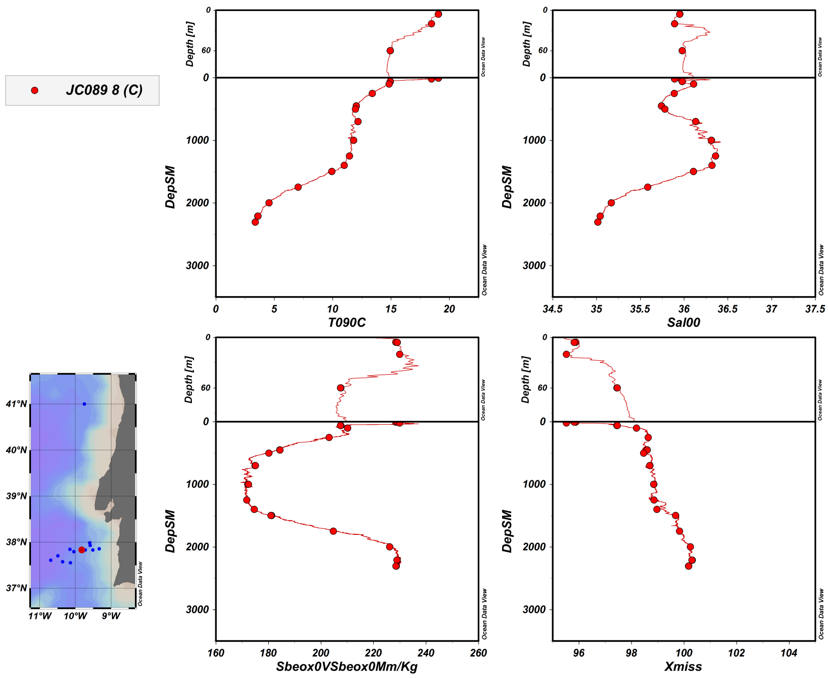


Figure 28. Profiles for cast 8 at Station JC089-09. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map

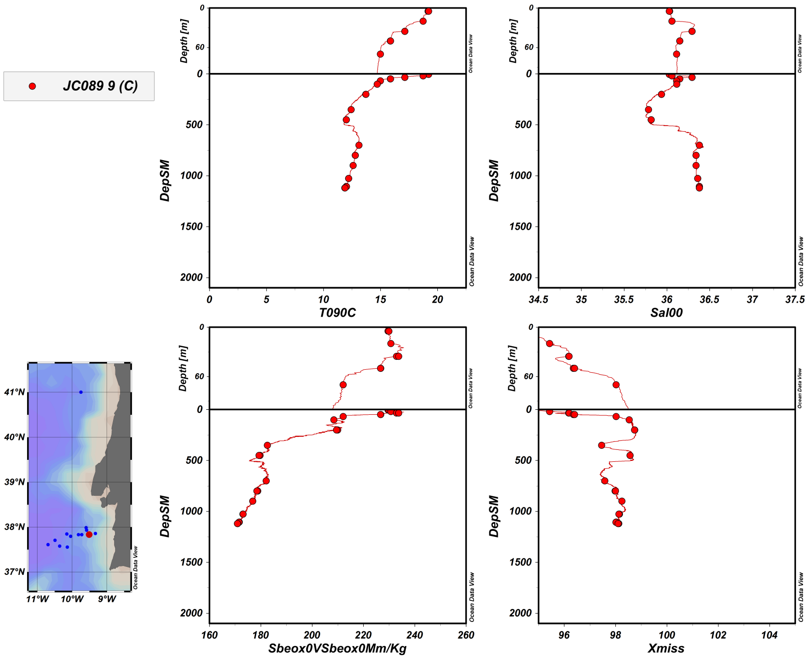


Figure 29. Profiles for cast 9 at Station JC089-10. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map.

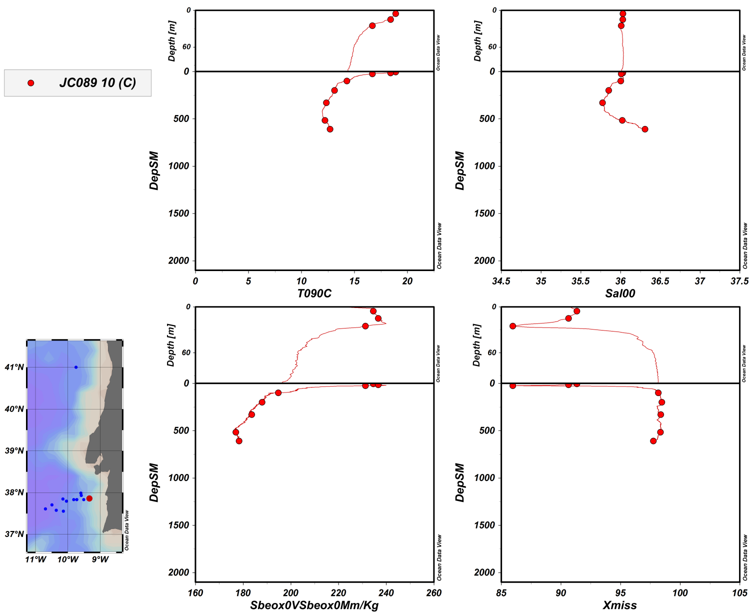


Figure 30. Profiles for cast 10 at Station JC089-11. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map.

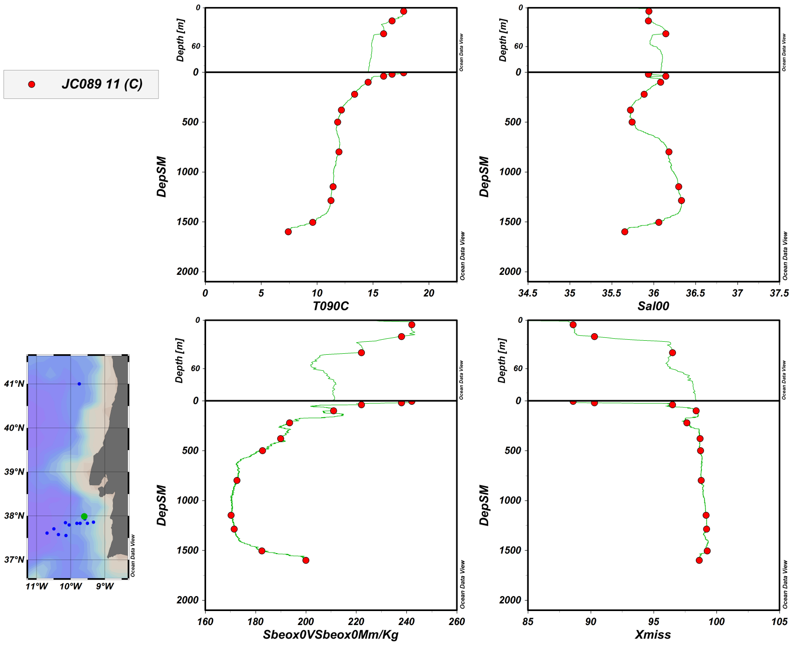


Figure 31. Profiles for cast 11 at Station JC089-12. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map.

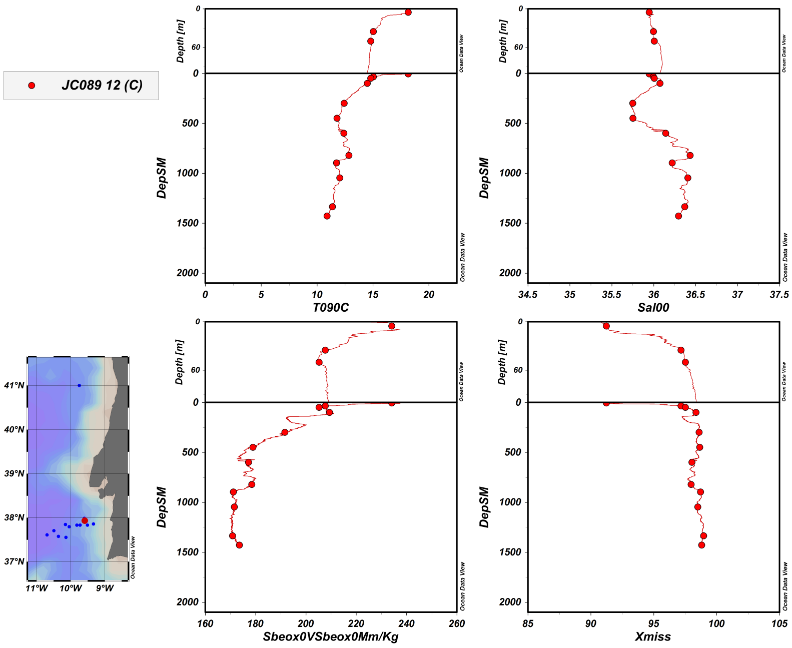


Figure 32. Profiles for cast 12 at Station JC089-13. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map

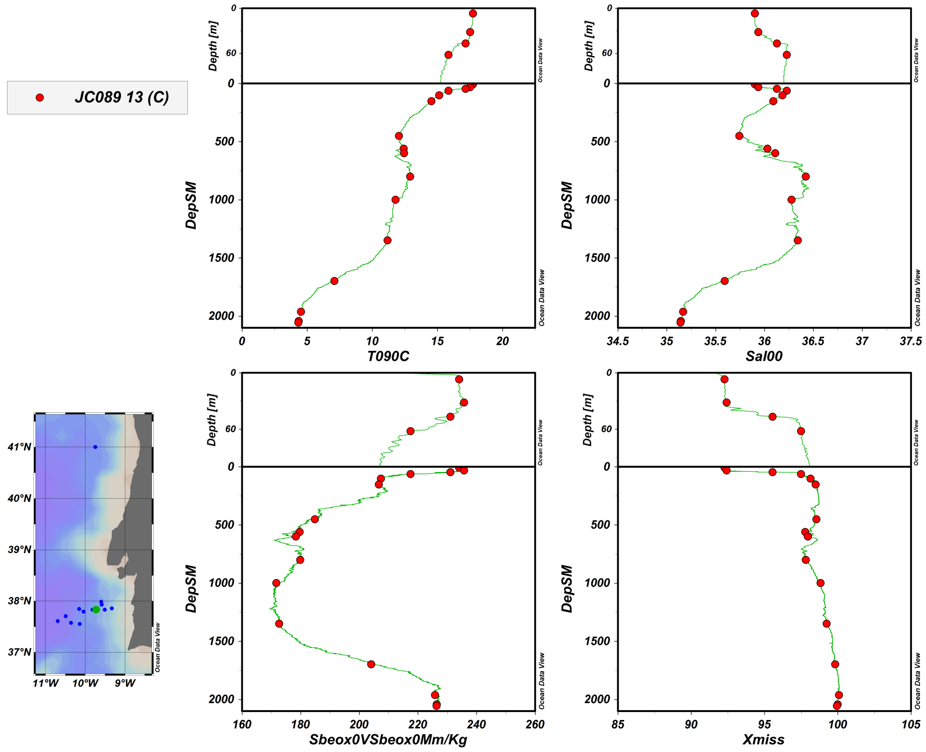


Figure 33. Profiles for cast 13 at Station JC089-14. *In situ* temperature, salinity, dissolved oxygen (uncalibrated) and transmissiometer (uncalibrated). Circles indicate depths bottles were fired. Cast location is shown on the map.

7.5.5 Water sample treatment and analysis

δ^{13}C of DIC

The aims of the measurements will be to use the δ^{13}C as a productivity and watermass-history tracer, and to better parameterise the controls on other tracers (eNd and ^{231}Pa/^{230}Th) that are related to water mass histories and particle scavenging.

Samples for the measurement of the stable isotopes of carbon (δ^{13}C) in dissolved inorganic carbon (DIC) were collected from the (titanium) rosette's 10L OTE bottles. The δ^{13}C samples were taken immediately once the OTE bottles were transferred into the sampling lab. δ^{13}C samples were taken into 250 mL glass bottles with ground glass stoppers. Water was drained directly into the sample bottle using silicone tubing to the bottom of the bottle to eliminate bubble formation. The bottle and cap were rinsed once with water from the OTE bottle before overflowing the sample bottle by at least 1 bottle volume before withdrawing the silicone tube carefully avoiding bubble formation. The stopper was then placed in the bottle and then removed so that 2.5 mL of sample could be removed (to allow for thermal expansion) and 50 mL of 100% $HgCl_2$ added to halt any biological activity. The stoppers and the inside of the neck of the bottles were then wiped with tissue to remove any moisture before the stopper – now greased with vacuum grease around the top – is replaced and fixed in place with a foam insert and plastic cover. The samples were then shaken to disperse the $HgCl_2$.

The distribution of samples collected for $\delta^{13}C_{DIC}$ is shown in Figure 34.

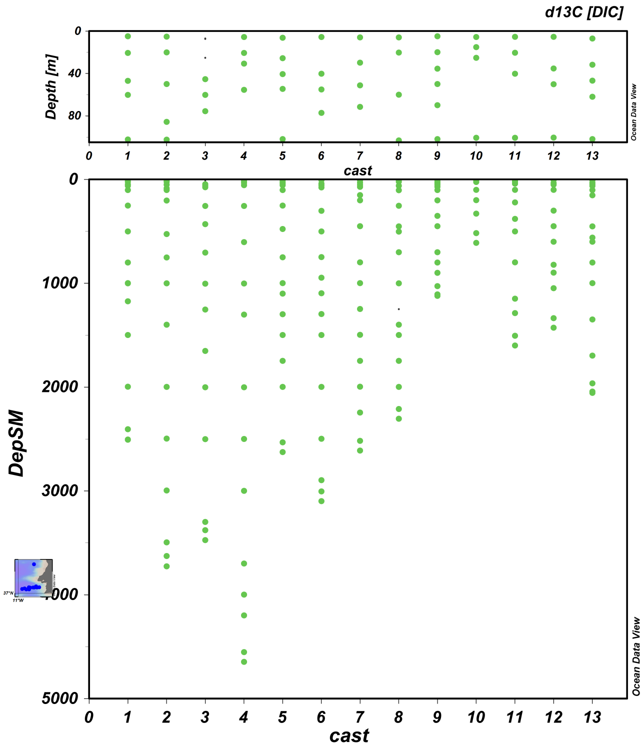


Figure 34. Green dots indicate depths at which samples were collected for $\delta^{13}C$ of DIC. Samples will be measured using a ThermoFisher Delta V stable isotope mass spectrometer at the University of Cambridge, equipped with a suitable gas bench.

Nutrients and $\delta^{15}N$ of nitrate

The objective is to understand the cycling of nitrogen isotopes at the Iberian margin, and critically observe changes in the isotopic composition of nitrate with changing water masses and oceanic processes. The coupled study of NO_3^- and N isotopes can be used to constrain the nitrogen budget of the Iberian margin. The isotopes of nitrate can help to identify inputs and losses of nitrogen as a macronutrient for biological processes.

Samples were collected from the titanium rosette, from every station at depths identified to represent either water masses or characterise the biology in the near surface ocean (Figure 35). Separate samples were collected for Nitrate isotopes and nutrient analysis Seawater for isotope analysis was filtered through an Acropak (0.45 µm) into acid clean 60 ml nalgene bottles and frozen at -20 °C. Two bottles were filled at depths, covering the whole water column at stations.

Samples will be analysed at the University of Edinburgh using the denitrifier method (Sigman et al., 2001, Casciotti et al., 2002).

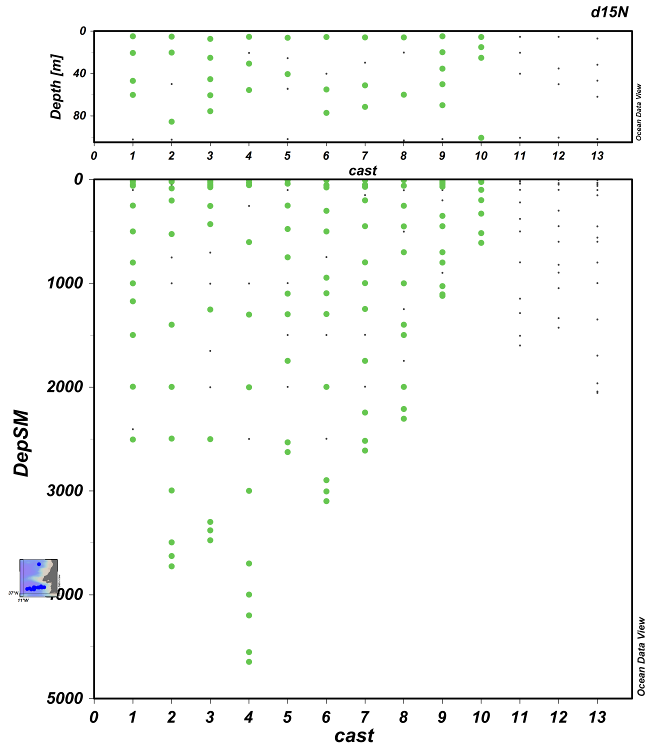


Figure 35. Green dots indicate depths at which nutrient and N isotope samples were collected. Samples will be analyzed at the University of Edinburgh.

$\delta^{18}O$ and δD of water

The objective is to measure the variation of oxygen and hydrogen isotopes of seawater in NE Atlantic water masses along the Iberian Margin. The isotope composition of water is a primary control, along with in situ temperature, on the $\delta^{18}O$ of foraminifer calcite. Measurement of $\delta^{18}O$ values of water masses local to the Iberian margin will aid in calibration of paleo proxies and inform about potential secondary controls on local palaeotemperature reconstructions.

Unfiltered water samples were collected in screw top glass vials. Samples were extracted through a silicone tube with a low flow rate to avoid entrainment of air bubbles during sampling. Bottle were overfilled twice and sealed with no headspace with parafilm to avoid evaporative fractionation of the isotopes.

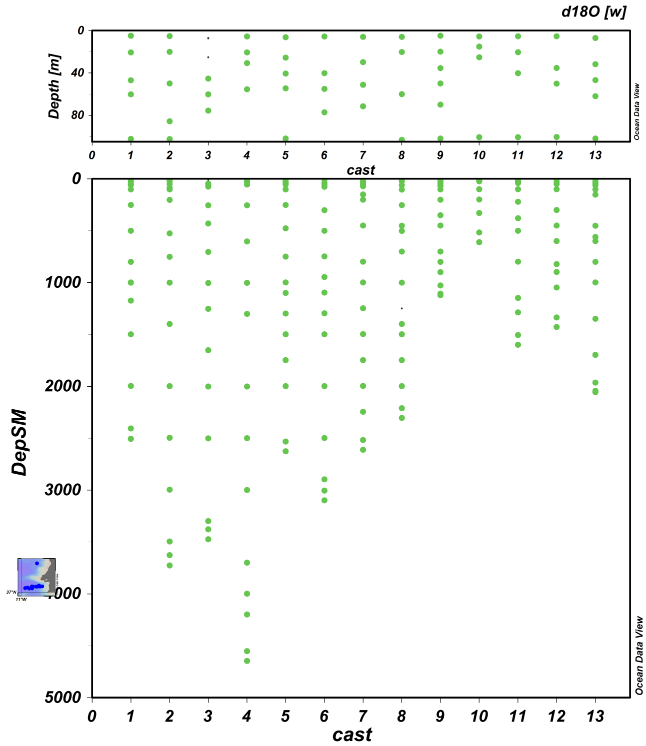


Fig. 36 Green dots indicate depths at which samples were collected for oxygen and hydrogen isotope analysis.

Rare Earth Elements

The rare earth elements (REEs) are the lanthanide group of the periodic table (also including Y). There elements have very similar chemistry in the ocean being slightly particle reactive and therefore removed by scavenging. While similar they demonstrate a systematic variability in their chemistry with increasing atomic mass becoming less particle reactive. The nature of the scavenging also controls the relative fractionation between the REEs. In addition to the scavenging behaviour two of the REEs Eu and Ce have different behaviours that allow sources and sinks of trace metals to be identified. Eu shows anomalously low concentrations in volcanic sources while Ce has a variable oxidation state so can be used to identify release from sediments in oxygen minimum zones.

250mL water samples were filtered directly from the OTE bottles using a 0.45um Acropak inline filter. The bottles were rinsed before being filled and were acidified to <pH2 with 10N HCl (trace metal free, quartz sub-boiling distilled).

Samples will be analysed by isotope dilution ICP-MS

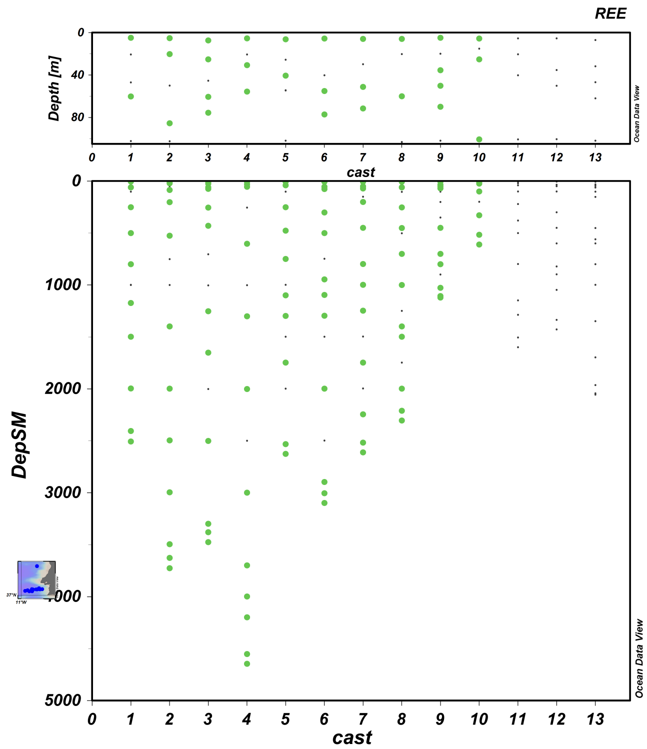


Figure 37. Green dots indicate depths at which REEs samples were collected.

^{230}Th and U-series nuclides

^{230}Th is produced in the water column from the decay of uranium. U is a conservative element in the ocean, only varying with salinity. The production rate of ^{230}Th is therefore constant. Thorium is very insoluble in the ocean and is therefore rapidly scavenged to the sea floor. The concentration of ^{230}Th in deep sea sediment is therefore thought to be solely a function of the overlying water depth (amount of U) and the rate of sedimentation. This has allowed measurements of sedimentary ^{230}Th to be used as a proxy for the sedimentation rate in paleoceanographic archives. This method however ignores the potential for Th redistribution in the water column and transfer of Th between the water and the sediment through the resuspension of sediment. In this region of strong advection of very distinct water masses of different origins we will measure the

^{230}Th content of the water to identify potential biases in the ^{230}Th normalisation method. In addition, some of the samples will also be measured for ^{231}Pa which behaves similarly to ^{230}Th in the ocean but with a slightly longer residence time. This isotope of protactinium has been proposed to be a potential proxy for advection and/or scavenging intensity. This sample set will enable us to assess the effect on resuspension of particulates on the use of this proxy.

5L water samples were filtered directly from the OTE bottles using a 0.45um Acropak inline filter. The bottles were rinsed before being filled and were acidified to <pH2 with 10N HCl (trace metal free, quartz sub-boiling distilled). Samples will be analysed by isotope dilution MC-ICP-MS following an Fe precipitation to isolate the actinides. This separation will also provide an aliquot for future analysis of Nd isotopes if required.

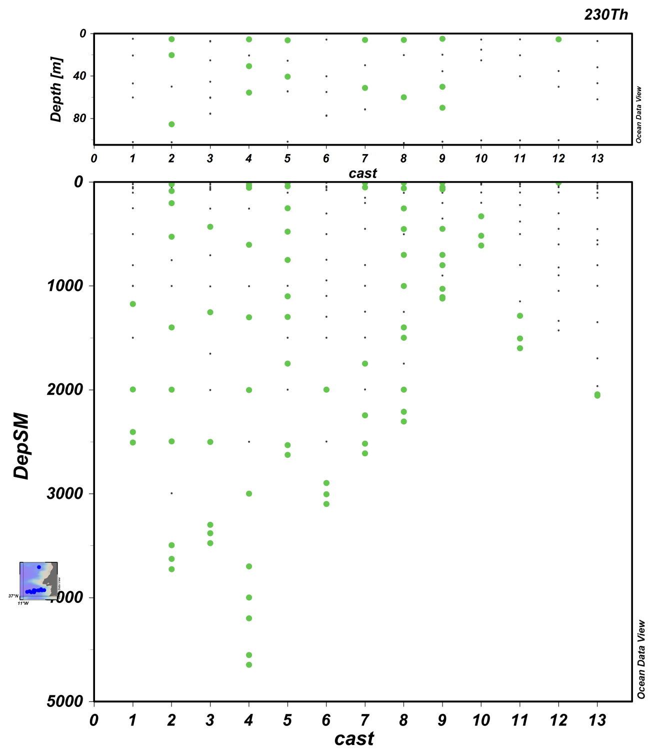


Figure 38. Green dots indicate depths at which ^{230}Th samples were collected.

Trace metals

Trace elements are vital for marine life, and therefore influence the marine ecosystem dynamics, the carbon cycle, and the global climate. The knowledge of present-day distribution of trace elements along the Iberian margin will allow their optimal use to reconstruct past climate conditions in this and in other upwelling regions. This will be achieved through calibration of the Element/Ca ratios in seawater and in calcite foraminifera tests, given that trace elements are incorporated directly into the foraminifera shells from seawater during their precipitation.

100 ml of seawater were collected in acid leached tubes, filtered and acidified by adding 16N HNO3 (seawater pH should be between 2 and 3), within 12 hours after collection. Between collection and filtration, the samples were stored in cold and dark conditions. After acidification, the samples were stored at room temperature in the darkness.

Seawater Mg/Ca and Ba/Ca will be analyzed by ICP OES at the MARUM – Center for Marine Environmental Sciences, University of Bremen, Germany.
Seawater Cd/Ca will be later on analyzed on an external lab to be determined.

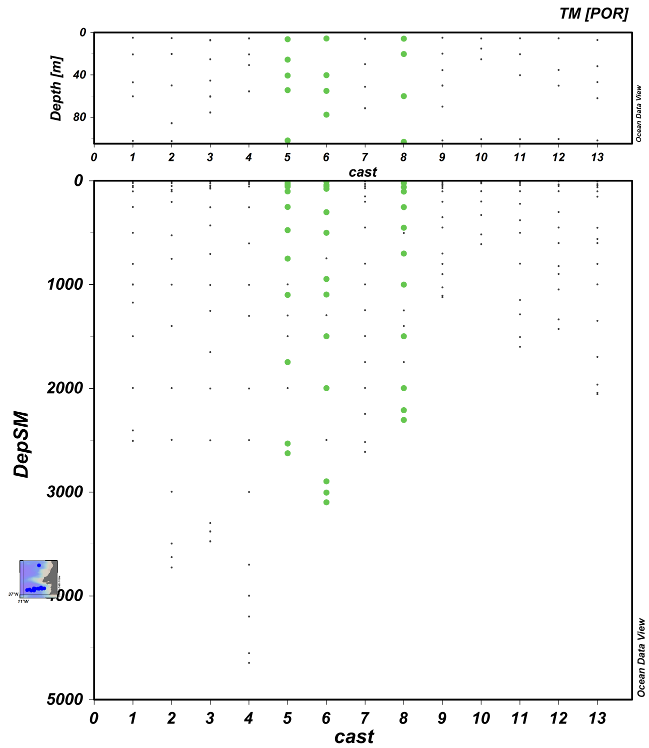


Figure 39. Green dots indicate depths at which trace metal samples were collected.

Seawater pH

As consequence of the rising atmospheric carbon dioxide level, pH values in surface and subsurface waters are declining leading to ocean acidification. Acidification of ocean water has consequences for aragonite- or carbonate-shelled plankton groups (e.g., Bednaršek et al., 2014) and thus in the longer term on the marine ecosystem. Few empirical pH measurements exist for North Atlantic water masses (Santana-Casiano et al., 2002; McGarth et al., 2012; Voelker, 2012). Voelker (2012) performed pH measurements along a water column profile in the JC089 study region and comparing the data from both cruises allows monitoring pH level changes over time.

250 ml plastic bottles were filled with seawater and a lid was closed tightly right after filling to minimize exchange with the atmospheric carbon dioxide. Sample bottles were brought into the clean lab for analysis.

The analysis was done on board, as soon as possible after sample collection, using a WTW (Wissenschaftlich-Technische Werkstaetten GmbH) pH meter 3110. The pH probe was calibrated with solutions of 4.01 and 7.00 and has an accuracy of ≤ 0.005 pH ± 1 digit. For measuring the pH value the probe was inserted into the bottom half of the opened sample bottle and the value noted down when the reading stabilized. For each sample, two measurements were made. A third measurement was added if the first two values differed significantly.

Bednaršek N., Feely R. A., Reum J. C. P., Peterson B., Menkel J., Alin S. R., Hales B., 2014. *Limacina helicina* shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem. Proceedings of the Royal Society B: 281 (1785), doi: 10.1098/rspb.2014.0123.

McGrath, T., Kivimäe, C., Tanhua, T., Cave, R.R., McGovern, E., 2012. Inorganic carbon and pH levels in the Rockall Trough 1991-2010. Deep Sea Research Part I: 68, 79-91.

Santana-Casiano, J.M., Gonzalez-Davila, M., Laglera, L.M., 2002. The carbon dioxide system in the Strait of Gibraltar. Deep Sea Research Part II: 49 (19), 4145-4161.

Voelker, A.H.L., 2012. EUROFLEETS Cruise Summary Report –IBERIA-FORAMS, R/V Garcia del Cid, Cruise Iberia-Forams, 10.09.2012 – 16.09.2012, Vigo (Spain) – Huelva (Spain). Marine Geology Group Report. IPMA Lisbon, p. 23.

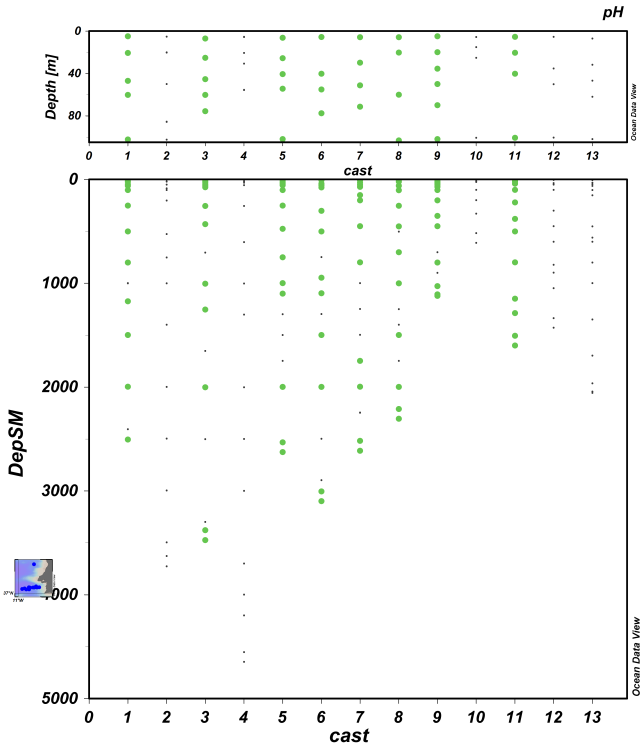


Figure 40. Green dots indicate depths at which pH samples were collected.

Silicon Isotopes

The isotopes of silicon provide information about silicic acid utilisation in the surface waters and also about the remineralisation of opal at depth.

250mL water samples were filtered directly from the OTE bottles using a 0.45um Acropak inline filter. The bottles were rinsed before being filled. The samples were not acidified before being sealed with parafilm.

Sample analysis will be carried out by MC-ICP-MS at the University of Bristol or NIGL by Dr Kate Hendry

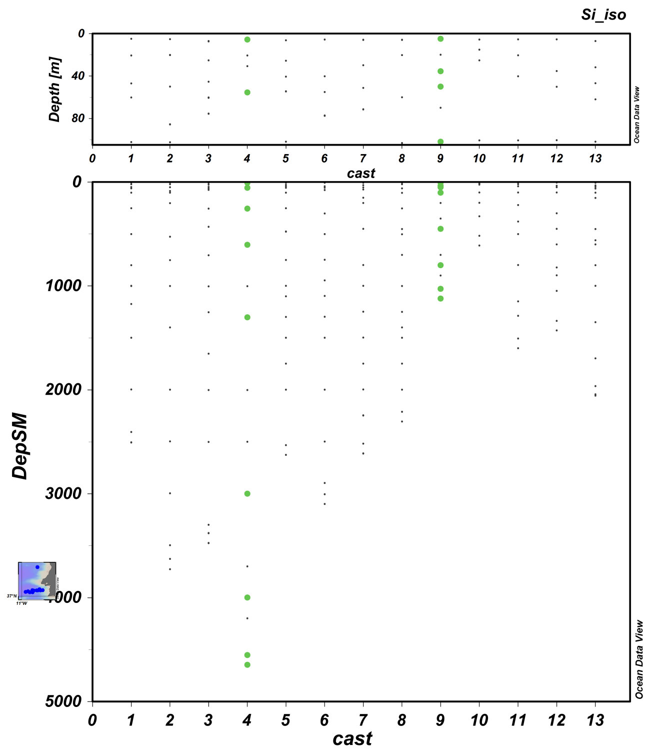


Figure 41. Green dots indicate depths at which Si isotope samples were collected.

Chromium Isotopes

The objective to measure the first Cr isotope profile from the North Atlantic. Cr is a redox sensitive metal that is becoming widely used in paleoceanography as a proxy of ocean anoxia during extreme climate events (OAEs). These samples will form part of a larger study to understand the fractionation if Cr isotopes in the modern ocean.

1L water samples were filtered directly from the OTE bottles using a 0.45um Acropak inline filter. The bottles were rinsed before being filled. The samples were not acidified before being sealed with parafilm.

Sample analysis will be carried out by double spike TIMS at Oxford university by De Ken Amor.

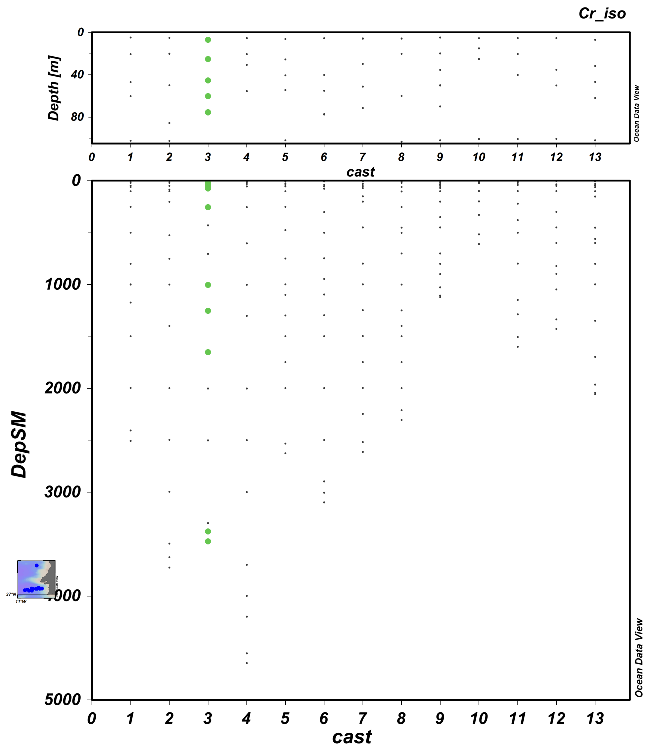


Figure 42. Green dots indicate depths at which samples were collected.

Archive Samples

We also collected water samples to be archived for future research. This may include the development of new paleoceanigarphic proxies to be applied to sediments on the Iberian margin.

1L water samples were filtered directly from the OTE bottles using a 0.45um Acropak inline filter. The bottles were rinsed before being filled and were acidified to <pH2 with 10N HCl (trace metal free, quartz sub-boiling distilled).

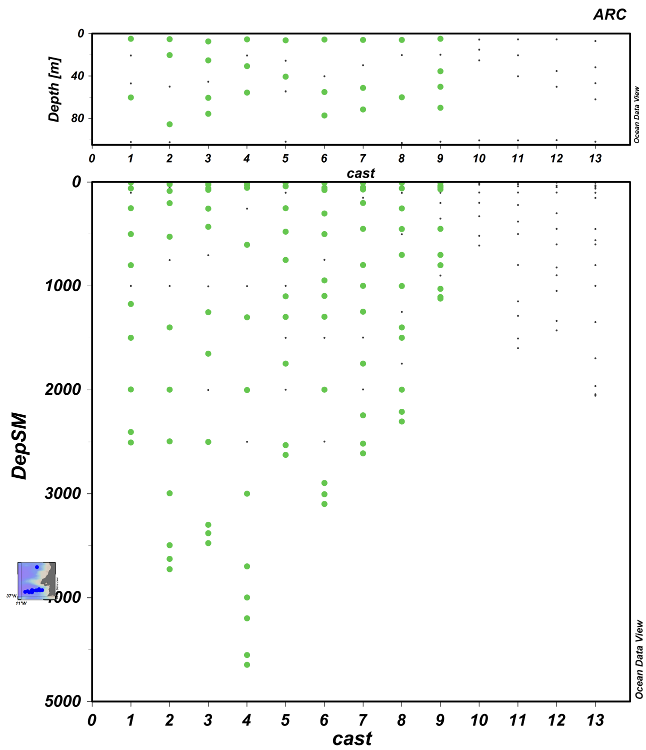


Fig. 43 Green dots indicate depths at which samples were collected.

7.6 Stand Alone Pumps (SAPS)

· In-situ pumping for POC collection using "Challenger" pumps

· Personnel

Daniel Montlucon: ERDW , ETH Zürich, Zürich Switzerland; contact: daniel.montlucon@erdw.ethz.ch Clayton Magill: ERDW, ETH Zürich, Zürich Switzerland; contact: clayton.magill@erdw.ethz.ch

Roles and responsibilities: Filters and samples handling, pump deployments

John Wynar: Sensors & Moorings Group, National Marine Facilities Division, National Oceanography Centre, Southampton; contact: jbwy@noc.ac.uk

Roles and responsibilities: Pump maintenance and deployments

· A brief rationale:

The overall goal of the in-situ pumping was to collect material from particle layers to examine the composition and transport of particulate organic carbon (POC) over the Iberian margin.

· Specific aims and objectives.

Continental margins generally maintain high biological production and along- and across-margin transport of POC are important distribution mechanisms and ultimately supply organic carbon to deep-ocean sediments. Our aim was to samples sinking particles as well as intermediate and bottom nephloid layers for geochemical investigations of organic matter. Carbon isotopic analysis (^{14}C and ^{13}C on bulk material and individual compounds) and molecular proxis analysis on POC collected in different intermediate particle layers as well as POC from bottom nephloid layers will allow us to tease apart the contribution of sinking POC versus re-suspended POC in observed surface sediments collected at different locations.

· Sampling methodology:

Seven SAPs were used during the cruise, s/n's: 02-03, 03-01, 03-02, 03-04, 03-05, 03-06 and 03-07 and a total of six deployments carried out. Units s/n: 03-02, 03-05 and 03-06 were fitted with original timer boards and were programmed using internal switches. The remaining SAPs had been upgraded to the new type timer boards and could be programmed via a serial port. A full summary of the performance of the SAPs is tabulated in JC089_SAP_log.doc.

·

SAP s/n: 03-07 failed to pump during the first two deployments although the timer reported correct functioning of the unit. Attempts to diagnose the problem suggest issues with the magnetic coupling although a remedy was not ultimately found. The unit was not deployed again on the cruise.

A total of 6 pumping stations were occupied. The pumping stations were at or near previously occupied CTD stations. Pump heights in the water column were determined after observations of transmissometer and fluorometer profiles for that station. The pumps were located to target the chlorophyll maximum, mid water particulate maximum(s) and bottom nephloid layer.

- Instrumentation details

The seven in-situ pumps were provided by the National Marine Facilities Division, National Oceanography Centre, Southampton.

Each pump was set up with a filter holder for 293 mm diameter filters, a mechanical flow meter, a rotary pump and a control housing containing an electronic processor and battery pack (each battery pack provided about 90 min of pumping time). Pump components were contained within a stainless steel frame allowing secure clamping on a wire for over-the-side deployment.

Calibration information- No calibration needed

- Processing methodology

All filters were folded and packed into clean, combusted aluminium foil. All filters were frozen after collection. Volumes of filtered water were recorded for each filter.

- Problems encountered:

- One of the six pumps never worked and was removed from the deployment set after attempted repair and two over-the-side sea trials. In addition for all deployments (except one) one pump in the set either did not work or did not work fully as programmed.

- Estimate of total data returns:

Each filter will be analysed for bulk composition (C,N) then extracted and analysed for a suite of biomarkers (quantification, deuterium and carbon isotopic compositions on selected compounds). We expect these measurements to take months to complete.

Table 19. Details of stand-alone pump deployments.

Date	Station	Lat (North)	Long (West)	Water depth (m)	Samples Taken (GF/F filters)	Comments
08-08-2013	**JC-089-03 SAP-1**	**37.685**	**10.463**	**3646**	**x7 293 mm GF/F pump depths @ 10, 65, 420, 1250, 2000, 3030, 3514 meters**	**Pump station 2 miles up current of CTD-2 Pump at Chla max (110 m) did not work Pump at 1275 m did not complete the 90 min pumping time**
12-08-2013	**JC-089-04 SAP-2**	**37.468**	**10.196**	**3539**	**x7 293 mm GF/F pump depths @ 35, 110, 775, 1275, 2025, 3025, 3635 meters**	**Pump station 2 miles up current (2nm due south) of MC-3 at SHAK-4 Pump at 2000 m did not work Pump at 1250 m turned off after 70 min**
18-08-2013	**JC-089-06 SAP-3**	**37.56**	**10.139**	**2635**	**x6 293 mm GF/F pump depths @ 10, 55, 750, 1400, 2100, 2610 meters**	**Pump station at CTD-5 station, 2 nm SE off SHAK-06**
20-08-2013	**JC-089-08 SAP-4**	**37.778**	**10.038**	**2607**	**x6 293 mm GF/F pump depths @ 5, 65, 795, 1495, 2145, 2577 meters**	**Pump station at CTD-7 station, 1 nm SE off SHAK-08 Pump at 1495 m did not work**
20-08-2013	**JC-089-09 SAP-5**	**37.825**	**9.869**	**2316**	**x6 293 mm GF/F pump depths @ 10, 50, 500, 1400, 1650, 2291 meters**	**Pump station at CTD-8 station, 1 nm off SHAK-09 Pump at 1400 m turned off after 60 min**
21-08-2013	**JC-089-10 SAP-6**	**37.833**	**9.511**	**1130**	**x6 293 mm GF/F pump depths @ 10, 45, 375, 525, 700, 1105 meters**	**Pump station at CTD-9 station off SHAK-10 Pump at 525 m turned off after 68 min**

Table 20. Details of performance of individual stand-alone pumps.

SAP S/N: 02-03

Deployment Date/Time	Depth	Battery V Start	Battery V End	Pump Time	Time Pumped	Volume Pumped	Comments
07.08.13/22:20	1250m	17.1/17.1	15.8/15.7	01:20	01:12	1339L	Low battery detect flag
12.08.13/18:13	1250m	18.0/17.8	15.9/15.7	01:30	01:10	1333L	Low battery detect flag
18.08.13/01:33	750m	18.1/18.0	15.9/15.8	01:20	01:20	1483L	
20.08.13/00:09	795m	16.8/16.8	15.8/15.8	01:18	01:18	1595L	
20.08.13/11:30	500m	17.0/16.9	16.0/15.9	01:18	01:18	1595L	
21.08.13/18:25	375m	18.5/18.4	16.1/16.0	01:18	01:18	1713L	

SAP S/N: 03-01

Deployment Date/Time	Depth	Battery V Start	Battery V End	Pump Time	Time Pumped	Volume Pumped	Comments
07.08.13/22:20	750m	17.3/17.5	16.3/16.3	01:20	01:20	1657L	
12.08.13/18:13	420m	18.1/18.2	16.2/16.2	01:30	01:30	1867L	
18.08.13/01:33	55m	18.1/18.2	16.4/16.4	01:20	01:20	1365L	
20.08.13/00:09	65m	17.0/16.9	16.6/16.5	01:18	01:18	1051L	
20.08.13/11:30	50m	17.2/17.2	16.7/16.6	01:18	01:18	1053L	
21.08.13/18:25	45m	17.5/17.6	16.5/16.5	01:18	01:18	1198L	

SAP S/N: 03-04

Deployment Date/Time	Depth	Battery V Start	Battery V End	Pump Time	Time Pumped	Volume Pumped	Comments
07.08.13/22:20	10m	17.4/17.4	16.5/16.5	01:20	01:20	1103L	
12.08.13/18:13	10m	17.8/17.9	16.3/16.3	01:30	01:30	1328L	
18.08.13/01:33	10m	17.9/18.0	16.5/16.5	01:20	01:20	1140L	
20.08.13/00:09	5m	17.3/17.2	16.4/16.4	01:18	01:18	997L	
20.08.13/11:30	10m	17.4/17.3	16.5/16.6	01:18	01:18	704L	
21.08.13/18:25	10m	17.5/17.4	16.5/16.5	01:18	01:18	548L	

SAP S/N: 03-05

Deployment Date/Time	Depth	Battery V Start	Battery V End	Pump Time	Time Pumped	Volume Pumped	Comments
07.08.13/22:20	2000m	17.01/17.01	15.30/15.31	1.5	1.5	1429L	
12.08.13/18:13	65m	17.35/17.37	15.38/15.36	1.5	1.5	989L	
18.08.13/01:33	1400m	18.4/18.4	15.00/15.11	1.5	1.5	1484L	
20.08.13/00:09	1495m	17.2/17.3	16.67/16.68	1.5	1.5	21L	Timer fault: countdown in “test mode”.
20.08.13/11:30	1400m	17.2/17.4	15.5/15.5	01:18	00:55	1150L	Using timer & end cap from #03-07. Low battery detect flag.
21.08.13/18:25	525m	19.2/19.2	15.2/15.4	01:18	01:00	1166L	Low battery detect flag

SAP S/N: 03-02

Deployment Date/Time	Depth	Battery V Start	Battery V End	Pump Time	Time Pumped	Volume Pumped	Comments
07.08.13/22:20	3000m	17.34/17.27	12.48/12.42	1.5	1.5	869L	Voltage below the 13.5V threshold!
12.08.13/18:13	3000m	17.46/17.43	12.47/12.41	1.5	1.5	893L	End voltage lower than 13.5V threshold.
18.08.13/01:33	2100m	18.2/18.2	12.46/15.73	1.5	1.5	1441L	One battery pack low
20.08.13/00:09	2145m	16.9/16.9	12.44/15.61	1.5	1.5	1349L	One battery pack low.
20.08.13/11:30	1650m	16.9/17.1	12.51/15.59	1.5	1.5	1387L	One battery pack low
21.08.13/18:25	700m	18.2/18.1	12.52/15.64	1.5	1.5	1485L	One battery pack low

SAP S/N: 03-06

Deployment Date/Time	Depth	Battery V Start	Battery V End	Pump Time	Time Pumped	Volume Pumped	Comments
07.08.13/22:20	3610m	17.68/17.52	16.32/16.28	1.5	1.5	1295L	
12.08.13/18:13	3514m	17.83/17.86	16.32/16.20	1.5	1.5	1326L	
18.08.13/01:33	2610m	18.7/18.9	16.30/16.26	1.5	1.5	1472L	
20.08.13/00:09	2577m	17.1/17.0	15.93/16.40	1.5	1.5	1377L	
20.08.13/11:30	2291m	17.3/17.2	16.10/16.35	1.5	1.5	1464L	
21.08.13/18:25	1105m	17.3/17.0	16.13/16.31	1.5	1.5	1460L	

SAP S/N: 03-07

Deployment Date/Time	Depth	Battery V Start	Battery V End	Pump Time	Time Pumped	Volume Pumped	Comments
07.08.13/22:20	85m	17.4/17.3	16.9/16.8	01:20	01:20	6L	Possible impeller housing over-tightened
12.08.13/18:13	2000m	18.1/18.2	16.8/16.8	01:30	01:30	28L	Timer counting down, motor turning but no pumping