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RRS *Discovery* Cruise 377 & 378

05 – 27 JUL 2012

Southampton to Southampton, UK

Autonomous ecological surveying of the abyss:
understanding mesoscale spatial heterogeneity
at the Porcupine Abyssal Plain

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2013

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ABSTRACT

Determining the distribution and abundance of life is challenging, especially in the deep sea where high pressure and other logistical challenges limit data availability to a tiny fraction of what is available for other systems. Most of Earth's surface is nonetheless covered by water > 2000 m deep. Life in these abyssal regions influences the burial of carbon and nutrient cycling. Long-term research has now shown that even larger animals in the deep sea can vary in density by orders of magnitude, with concurrent changes in average body size, over periods as short as months. These variations are widely believed to be linked to climate-driven variation in the food supply to the deep sea. Similarly, biogeography studies have found that over distances approaching 100 km or more, the abundance of deep-sea life is related to surface productivity in the waters above. Thus the deep sea could be readily impacted by processes that alter surface ocean conditions like climate change, fishery activity, or ocean iron fertilisation.

While there has been an increase in the understanding of how climate and surface processes affect deep-sea communities, the ability to understand these links further is thought to be limited by sampling error from undetected habitat heterogeneity (i.e. irregular or uneven habitat distributions). Features like hills, valleys, depressions, small rock outcrops, and biogenic mounds add to habitat complexity, but links between such features and the animals that live among them are very poorly resolved in abyssal plain habitats using current methods. We proposed a new approach using the autonomous underwater vehicle (AUV) Autosub6000 to survey ecologically the Porcupine Abyssal Plain (PAP) Sustained Observatory to address a key question: Are spatial patterns in abyssal habitat features (like bathymetry, seafloor cover of phytodetrius [i.e. food availability], suspended solid concentration) related to spatial patterns in photographed life (density, dispersion, or biodiversity) at spatial scales from <1 m^2 to about 100 km^2?

Objectives

1. We created high-resolution ecological maps at scales of <1 m^2 to 100 km^2.
2. We will then test tractable hypotheses focusing on if any observed faunal distributions are linked with the spatial patterns of other fauna, habitat, food availability, or environmental conditions.
3. We will use the results to improve estimates of deep-sea biodiversity and ecosystem function of megafauna and relate the findings to factors such as food availability.
4. We will enhance UK capability in evaluating abyssal ecology and facilitate future time-series ecological research surveys.

Activities

- *Crude oil spill impact experiments*
- *CTD rosette-based prokaryotic sampling.*
- *Megacoring*
- *Box coring*
- Seabed High Resolution Imaging Platform *(SHRIMP) surveys*
- Autosub6000 surveys including acoustic mapping and photography

KEYWORDS	
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1.0 Background & Objectives

Determining the distribution and abundance of life is challenging, especially in the deep sea where high pressure and other logistical challenges limit data availability to a tiny fraction of what is available for other systems. Most of Earth's surface is nonetheless covered by water > 2000 m deep. Life in these abyssal regions influences the burial of carbon and nutrient cycling. Long-term research has now shown that even larger animals in the deep sea can vary in density by orders of magnitude, with concurrent changes in average body size, over periods as short as months. These variations are widely believed to be linked to climate-driven variation in the food supply to the deep sea. Similarly, biogeography studies have found that over distances approaching 100 km or more, the abundance of deep-sea life is related to surface productivity in the waters above. Thus the deep sea could be readily impacted by processes that alter surface ocean conditions like climate change, fishery activity, or ocean iron fertilisation.

While there has been an increase in the understanding of how climate and surface processes affect deep-sea communities, the ability to understand these links further is thought to be limited by sampling error from undetected habitat heterogeneity (i.e. irregular or uneven habitat distributions). Features like hills, valleys, depressions, small rock outcrops, and biogenic mounds add to habitat complexity, but links between such features and the animals that live among them are very poorly resolved in abyssal plain habitats using current methods. We proposed a new approach using the autonomous underwater vehicle (AUV) Autosub6000 to survey ecologically the Porcupine Abyssal Plain (PAP) Sustained Observatory to address a key question: Are spatial patterns in abyssal habitat features (like bathymetry, seafloor cover of phytodetrius [i.e. food availability], suspended solid concentration) related to spatial patterns in photographed life (density, dispersion, or biodiversity) at spatial scales from <1 m^2 to about 100 km^2?

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1. We created high-resolution ecological maps at scales of <1 m^2 to 100 km^2.
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3. We will use the results to improve estimates of deep-sea biodiversity and ecosystem function of megafauna and relate the findings to factors such as food availability.
4. We will enhance UK capability in evaluating abyssal ecology and facilitate future time-series ecological research surveys.

Null Hypotheses

$H_0$1) Spatial patterns in habitat features (bathymetry, seafloor cover of phytodetrius [food availability], suspended solid concentration) do not significantly covary (p > 0.05) at spatial scales from <1 m^2 to about 100 km^2.

$H_0$2) Spatial patterns in abyssal benthic megafauna (density, dispersion, community composition and structure, or biodiversity) do not significantly covary (p > 0.05) at spatial scales from <1 m^2 to about 100 km^2.

$H_0$3) Spatial patterns in abyssal benthic megafauna exhibit no significant covariation (p > 0.05) with spatial patterns in habitat features at spatial scales from <1 m^2 to about 100 km^2.

Activities

- Crude oil spill impact experiments
- CTD rosette-based prokaryotic sampling.
- Megacoring
- Box coring
- Seabed High Resolution Imaging Platform (SHRIMP) surveys
- Autosub6000 surveys including acoustic mapping and photography

Expectations

- We expect that POC settling and resuspension rates will vary spatially in response to vertical bathymetric relief on the order of 1-100 m or more (over distances of about 100 m to 10 km) leading to important differences in suspended solid concentration in the water ~2m above the seafloor, seafloor coverage of phytodetritus, the quantity and quality of settled POC, and sediment particle size distributions between higher and low-lying areas.
- We expect that spatial heterogeneity in these seafloor attributes will relate to non-random distributions in megafauna abundance.
- We expect that as the scale of features such as abyssal mounds and hills change, so will the scale of distribution patterns of megafauna.
- We expect that the results will elucidate a major source of previous sampling error and allow for an order of magnitude improvement in the accuracy of estimates.
- We expect reliable abundance estimates will be possible for a greater proportion of rare taxa, when compared with previous methods, thus improving biodiversity estimates.

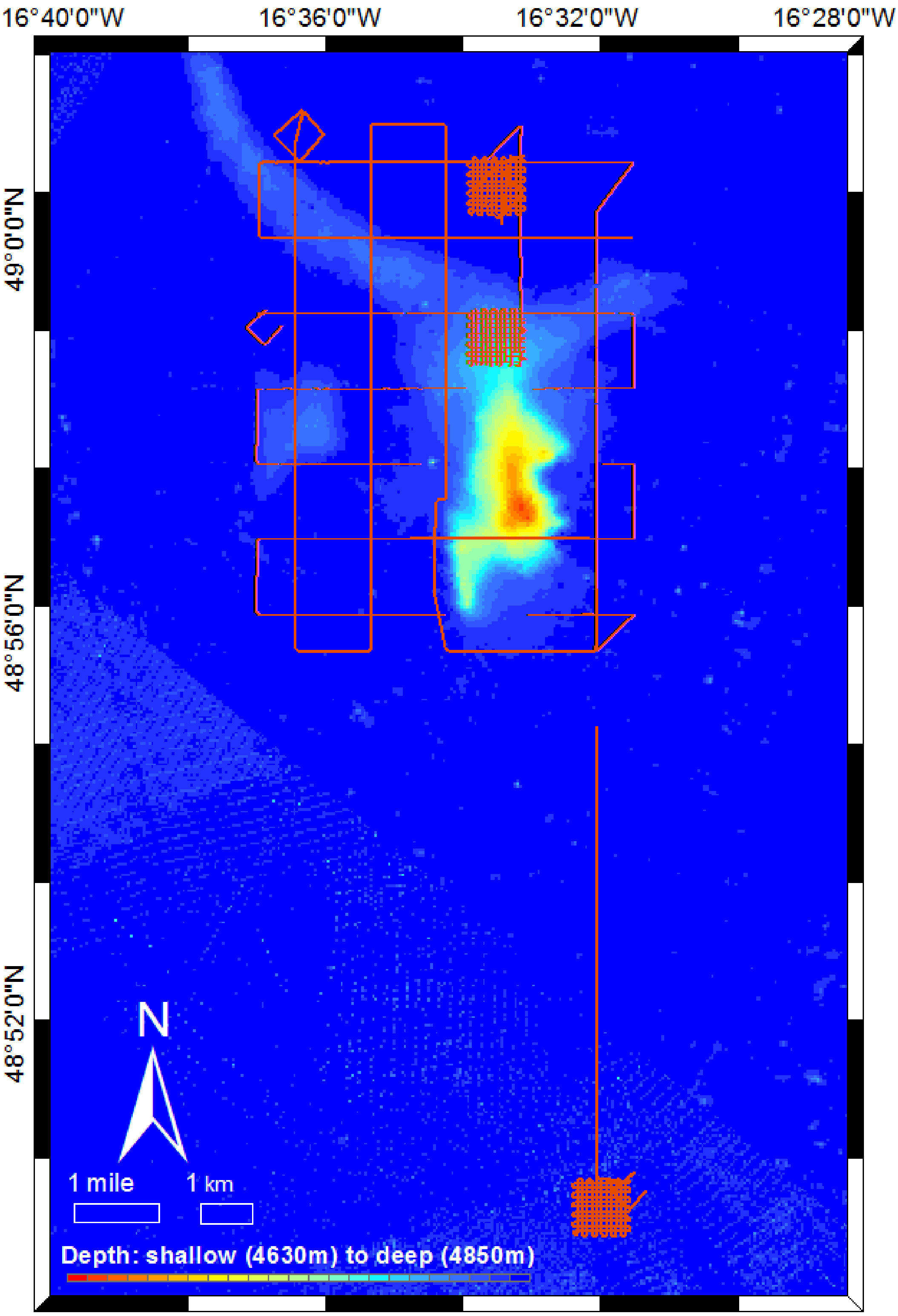

Figure 1.1. Chart illustrating locations of Autosub6000 seabed phototraphy in AESA study area in the top half of the chart and the PAP Central location as indicated by the dense set of survey tracks in bottom right of the chart.

2.0 Narrative

5 July: We left port at 13:00 on the 5th with the unusual pleasure of leaving from NOC, Southampton with many colleagues waving us off. We went in to calming seas and had good weather throughout our transit. In the early afternoon we had a science meeting to brief everyone on the basic science objectives of the cruise. We then had a fire and boat drill. We discussed survey methods and the finer points of how we might design the survey grid.

6 July: In the morning meeting we discussed if/how we might core using the plasma line with a depressor weight. A strong preference to use the wire rope instead was indicated because it has less drag and more mass to steady the line, which was used. They began prepping it, but later in the day discovered the load readings through the CLAM were not coming through for any systems. This limits the ability to core, which is not sensible without load readings. Another issue to arise was that the CT van cooling system was not working, most likely due to an issue with either a missed reset switch or cooling water rate, or both. The notes indicate it needs 1.1 l/s, but the exit rate of the discharge was 0.71 l/s. After various efforts it was started and left to run overnight. The CT room was also having trouble getting to temperature. It had been on all day and only got down to 15 C, while it was set to 8C.

7 July: The CT van cooling system stopped overnight and the CT room did not get below 14C. The CT van cooling system was restarted by using the switch 4 setting which had reverted back to ‘standby’, so it was switched to ‘on’. We proceeded upon first arriving at the station to conduct a CTD to collect water for the oil impact incubations. The CTD had a few bottles that failed to trip, but otherwise worked well and the needed water was collected. After the CTD was up we needed to replace faulty tachomter for the main propulsion system and waited on standby. The CT room was serviced mid morning and was soon down to 8C after receiving a coolant boost. To utilize the standby time we began testing the USBL pole and beacon system that will be used for tracking Autosub6000. A problem with the pole was identified and it was taken out of service.

The issues with the wire rope winch developer further with a serious scrolling issue identified. A plan to address them was put in place with assistance from shore. A load test was repeated running the wire through a different sheave, followed by deploying a weight on the wire to track the scrolling with a dip to 950 m depth at 15 m/ min, 30 m/min, and 60 m/min. The tests were successful and before too long we were able to start collecting cores for the incubation experiment.

8 July: We finished collecting cores for the incubation experiment early in the morning and began to transit to PAP. During the day we continued to hone our survey design including the latest calculations on endurance and desired testing. We stopped at about 21:00 to do a single deep wire test at 4800 m depth which ran into the next day.

9 July: We started a megacore around 5:30 which was on deck by about 9:30. While the Autosub6000 was undergoing final checks we continued megacoring. Because the first set came up with 3 untripped tubes, we decided to apply petroleum jelly to the rods on which the the catcher slides in order to trip it. The next deployment had only one catcher fail with one other tube loosing mud.

We then proceeded to prepare for launch of Autosub6000 for its initial survey and camera testing. First the recovery of the PES fish went wrong when the winch rendered and the fish went into free fall until it reached the termination, which held it fast. We then used a snatch block on the fish tether to pull it up, followed by several stop offs while the slack line was wound onto the spool. This caused a delay in the launch of about an hour. The MARS fish was still operational and was deployed just after the other was recovered. By about 17:30 Autsub6000 was launched and making its decent. While tracking it down, it stopped communicating and its surface signal was heard some 20 min later. Shortly after sight on the surface 'smoke' was noticed coming from the vehicle. By the time it was getting nearby, the smoke had stopped, and a slight slick could be seen around the sub. The smell of burnt electrical components was intense when the sub was just alongside. After recovering the vehicle and the cover panels were removed, charred oil was noted to cover some of the forward components. Early indications were that the damage may have been limited to one battery.

10 July: By morning, we were able to confirm that the other batteries were still functional. Preparation to re-deploy the sub began with some modifications to mission plans. While the sub was being prepped we proceeded to do a single CTD cast and continue with megacoring in the AESA area. The first oil and gas impact experiment was also finished overnight with the incubation cores sliced for either macrofauna or prokaryote analysis.

11 July: We continued coring as the sub was not fully prepared to dive and the weather for the next 24 hrs was not looking very good either. Troubleshooting continued on the sub and coring continued overnight.

12 July: We started to transition from the flatter area sites to the sites on the higher topography, with good success, although the B1 site had a failure where the corer seemed to go onto its side and then, as the strain came back on the wire, the pull rods of the corer bent slightly. Once on deck and the corer was secured with its safety pin back in place, we proceeded to replace the rods with spares. The system was back in the water shortly. We had hoped to launch Autosub around mid day, but troubleshooting continued throughout the day and into the evening. We were able to launch the sub with the vertical camera ready for testing just after 20:00. We soon realized that the fixes to the battery issue did not work.

13 July: The vehicle eventually surfaced and was recovered just before 02:00. We then proceeded to conduct several more cores throughout the day and into the next.

14 July: We conducted a second CTD for prokaryote work with good recovery and sample processing. We also collected a volume of water from 1000 m depth to contribute to the oil impact experiment work. By evening we launched Autosub6000 for its third mission, which was focused on bathymetric mapping with some camera testing. By late evening it was apparent that the two older batteries were not operating as expected. However, we decided to continue the run on the remaining power and recover around first light the following day.

15 July: Upon recovering the vehicle we soon learned that the camera test had gone well, and there was a sizeable amount of great bathymetric data. The great image data provided some excitement to the science party, as well as the crew. Several people could be found crowed around the image workstations throughout the day. The only modifications for the next mission were to swim a bit slower, to check ADCP feedback, and check flash alignment. Coring continued throughout the day.

16 July: We started our first PAP central megacore in the early morning. The weather had deteriorated a bit, but was still workable. The core had a rough pull out, but still returned 7 out of 10 tubes. Buy about 13:00 we were ready for another Autsub6000 launch to do bathymetric mapping and camera testing, this time with both cameras. The sub again lost its two older batteries early in the mission, so the mission length was reduced and we tracked the sub for its entire dive.

17 July: When we downloaded the data it became apparent that there was a problem in the flash setup. The bathymetric data looked good, however. We then proceeded to start our first boxcore, which did not fire properly. In the late afternoon we returned to the AESA area and proceeded to launch the next Autosub6000 mission, which was to cover just over three of the N-S oriented 10 km transect lines.

18 July: The recovery of the sub brought great news when we learned that the vehicle covered ~36 km of transect and ~58 k images, half of which came from the vertical camera and half from the oblique camera. The vertical images still looked good, but quick inspection showed that there was significant backscatter effect due to the proximity of the flash to the camera. We collected two good boxcore samples from PAP during the day and into the evening. Then, Autosub6000 was prepped for launch about 23:30. However, an issue with the forward camera strobe delayed the launch.

19 July: By just after midnight the sub was ready to go, but with the forward facing camera switched off. There appeared to be an issue where the strobe would stop, the camera would successfully reset, but the strobe would not. Given various issues, we launched with just the vertical camera. The expected mission duration was such that it was not sensible to attempt our next coring activity. For reasons not immediately known, the older batteries did not seem to switch off mid dive as they had for the last several dives. So the mission extended until about 12:30. The downward camera worked well and we worked to curate the images and plan the next mission. We planned another mission, which covered the remaining AESA area work that was feasible. Autsub6000 was launched in the late evening with both cameras working and a longer mission planned than had been done yet. In the mean time preparations for SHRIMP continued, which was to be used in an area where Autosub could not go without more testing of the collision avoidance system.

20 July: The sub batteries continued to perform well into the next day. However, the SHRIMP preparations were delayed due to difficulties in getting the wire terminated. We continued to monitor Autosub during SHRIMP preparations.

21 July: By the early morning, the termination and deck testing were finished, taking about a day longer than anticipated. Later, the sub was prepped for launch at PAP for a fine scale survey and then a run up to the AESA area for more bathymetric work.

22 July: The sub came to the surface well before breakfast and we prepared it for one last dive at PAP, this time with collision avoidance on in order to fly over the more complex topography. While the sub was recharging and the previous dive's data was downloaded, we did a CTD cast. The cast was initially delayed by a winch scrolling issue, which was corrected after about an hour. The CTD was only taken to 2500 m depth to avoid delay in getting the sub back in the water for one final dive. This cast also had the sub's LSS sensor placed on the CTD rosette in order to calibrate its outputs against the CTD transmissometer. The sub was back in the water by about 15:00. The collision avoidance did appear to work

well, but the vehicle made contact with the seafloor more than once. The camera systems unfortunately did not operate after the first 1000 m of the dive. After the sub was onboard we were underway for Goban Spur before the end of the day.

23 July: A subsequent investigation found corrosion on one of the connecting cables, potentially explaining the outcome of the previous camera failure. Plans for the next dive in the Celtic Sea started to firm up as both location charts and projected mission times were now ready.

Once we arrived at Goban Spur we proceeded to conduct CTD and megacore work in support of the oil impact experiments, as well as one additional core drop done in support of research on molecular ecology for ecology of the margin and connections with Whittard Canyon.

24 July: These stations went well and we were able to move onto the Glider pick up point by early afternoon. The glider pickup went very well and the crew did a great job manoeuvring the ship and picking it out of the water. We were quickly on to our last stop, but diverted to Penzance unexpectedly due to an illness with one of the cruise participants.

25 July: We arranged a Lifeboat to meet us near Penzance and the participant was disembarked safely. We then proceeded again to the Haig Fras survey site, the last deployment site of the cruise. We arrived at 17:30 and quickly had the sub in the water. After a period of programming over the WiFi link, the sub began a series of three mini-missions over the site, for multibeam, photography, and side scan sonar, which ran overnight.

26 July: Because of the diversion we were given a few extra hours for the survey. The Master had also arranged for a route that would save a bit of time on the return, which required Coast Guard permission. We recovered the sub just in time to make our new arrival time in Southampton for 13:00 on the 27th. The second core experiment was finished in the mid afternoon and the cores were sliced as usual and the kit was cleaned and left ready for packing the following morning.

27 July: In the morning the teams packed up any equipment that was not yet packed and staged boxes using pallets and cages for a speedy demob.

3.0 Research strategy & Outcomes

3.1 Crude oil spill impact experiments - Charlotte Main et al.

We investigated deep sea sediment community responses to crude oil hydrocarbons by *ex situ* experiments performed at Goban Spur. Two ship-based experiments were run to study the effect of hydrocarbons on deep sea sediment community oxygen consumption (SCOC). Sediment cores (10 cm internal diameter acrylic tubes) were collected using the megacorer from the continental slope of the Goban Spur, southwest of Ireland at the positions and depths shown in the table below. The majority of the sediment cores were converted into sealed microcosms and were incubated in experiments. Cores were also collected, sliced and preserved for later analyses without being used in the experiment (background cores).

Hydrocarbons were introduced to sediment cores using dilutions by estimated volume of core overlying water with a water accommodated fraction of crude oil (WAF). The WAF was prepared at the start of the experiment using bottom seawater, collected with Niskin bottles on the CTD at the same approximate position and time as the sediment coring. Crude oil had been obtained from the Wytch Farm oilfield, Dorset, UK (obtained on 14th June 2012 from a private company). A standard low energy mixing procedure was used to prepare WAF in a temperature-controlled room (set at ambient bottom water temperature, 9.2 °C).

WAF was siphoned directly from the preparation bottle into sediment cores to produce oil treatment levels based on the estimated volume of water in the tube above the sediment-water interface. Eight replicates of serial dilutions of 25% and 50% were allocated in a random sequence to cores. Eight replicate cores were controls: 25% of the overlying water volume of these control cores was exchanged with uncontaminated bottom seawater. At stages during the WAF addition process, a 450 ml sample of the WAF was siphoned into a 500 ml bottle and preserved with 50 ml hydrochloric acid of specific gravity 1.18. These samples were analysed as soon as possible following the conclusion of the research cruise for total monoaromatic hydrocarbon (MAH) concentration (and total hydrocarbon concentration). This was to confirm the assumption of starting concentrations of MAHs in the WAF stock solution from which serial dilutions were made.

Following addition of WAF/water, the sediment cores were sealed immediately with no headspace of air left at the top. The cores were incubated at 9.2°C. During the incubation period the cores' overlying water was stirred manually with a mechanical stirrer for approximately 10 seconds every two hours and for 10 seconds preceding measurement of oxygen. The WAF used for hydrocarbon treatments in the second experiment was aerated for 30 minutes prior to its use in the experimental cores, so as to produce a mixture that was 100% saturated with oxygen. Seawater added to the controls was not aerated in the same way, although it was drawn from a container that was open to the atmosphere and was 100% saturated with oxygen.

Once the microcosms had been sealed, reduction in oxygen concentration over the period of the incubation was measured in each individual core using pre-fixed optical sensor spots and Fibox system (PreSens).

Table 3.1.1. Summary of cores collected for each experiment run at Goban Spur.

Experimental run	Date collected	Time run (days)	Number of cores incubated	Number of background cores collected	Treatments (8 replicates)
1	8 July 2012	1	24	4	25 % seawater (control), 25% WAF, 50% WAF
2	23 August 2012	2	24	6	25 % seawater (control), 25% WAF, 50% WAF

Table 3.1.2. Details for the second of the two experiments at Goban Spur. Experimental cores: ID 110-133. Cores for background samples sliced and preserved immediately: ID 134-139. All data relate to the second of two experiments performed using Goban Spur sediment cores. T1 = treatment level 1 (25% serial dilution of core overlying water with water accommodated fraction of crude oil, WAF); T2 = treatment level 2 (50% serial dilution with WAF); C = 25% core overlying water replaced with uncontaminated bottom seawater (control); F = cores preserved in formalin for later quantification of macrofauna biomass; P cores frozen for later analysis of prokaryote biomass.

Core ID	Station	Latitude	Longitude	Depth (m)	Treatment	Preservation method
110	D377-56	49º 35.517 N	011º 50.872 W	996	T1	F
111	D377-56	49º 35.517 N	011º 50.872 W	996	T2	P
112	D377-56	49º 35.517 N	011º 50.872 W	996	C	F
113	D377-56	49º 35.517 N	011º 50.872 W	996	T1	P
114	D377-57	49º 35.521 N	011º 50.828 W	995	T2	F
115	D377-57	49º 35.521 N	011º 50.828 W	995	C	P
116	D377-57	49º 35.521 N	011º 50.828 W	995	C	F
117	D377-57	49º 35.521 N	011º 50.828 W	995	T2	P
118	D377-57	49º 35.521 N	011º 50.828 W	995	T1	P
119	D377-58	49º 35.424 N	011º 50.733 W	994	C	P
120	D377-58	49º 35.424 N	011º 50.733 W	994	T1	P
121	D377-58	49º 35.424 N	011º 50.733 W	994	T2	F
122	D377-58	49º 35.424 N	011º 50.733 W	994	C	F
123	D377-58	49º 35.424 N	011º 50.733 W	994	T1	F
124	D377-59	49º 35.426 N	011º 50.847 W	992	T2	F
125	D377-59	49º 35.426 N	011º 50.847 W	992	T2	P
126	D377-59	49º 35.426 N	011º 50.847 W	992	T1	F
127	D377-59	49º 35.426 N	011º 50.847 W	992	C	F
128	D377-59	49º 35.426 N	011º 50.847 W	992	C	P
129	D377-60	49º 35.488 N	011º 50.816 W	992	C	P
130	D377-60	49º 35.488 N	011º 50.816 W	992	T2	P
131	D377-60	49º 35.488 N	011º 50.816 W	992	T2	F
132	D377-60	49º 35.488 N	011º 50.816 W	992	T1	F
133	D377-60	49º 35.488 N	011º 50.816 W	992	T1	P
134	D377-56	49º 35.517 N	011º 50.872 W	996	-	P
135	D377-57	49º 35.521 N	011º 50.828 W	995	-	F
136	D377-58	49º 35.424 N	011º 50.733 W	994	-	P
137	D377-59	49º 35.426 N	011º 50.847 W	992	-	F
138	D377-59	49º 35.426 N	011º 50.847 W	992	-	F
139	D377-60	49º 35.488 N	011º 50.816 W	992	-	P

3.2 CTD rosette based prokaryotic sampling. -Annette Wilson et al.

Water from three CTD casts (D377_016, D377_033, D377_053), usually at 12 sample depths, were collected to assess the microbial community and functioning in the water column at the Porcupine Abyssal Plain.

Methodologies: Water was collected using 10 litre niskin bottles attached to the CTD rosette and filtered through a two-stage filtration set up. The sample depths were typically 10 m, 25 m 80 m, 100 m, 500 m, 1000 m, 3000 m, 3050 m, 4750 m, 50 metres above bottom (m.a.b.), 25 m.a.b. and 10 m.a.b., with priority given to those the surface and seafloor and adjustments made in accordance to the chlorophyll max. Water from only seven sample depths was collected from the third cast (D377_053, CTD cast #6) due to time constraints. Excess of 10 litres of water from each depth was collected in acid washed (1% HCl) jerry cans. All tubing and jerry cans were rinsed with sample water before processing. Priority one samples, were processed immediately and priority two and three samples were stored at 2 °C until processing. Water was pre filtered through a GF/F (Whatman, 47mm) filter. These filters were changed if and when they appeared green/brown and the flow was reduced. Water was then filtered through a Sterivex-GV, (sterile, enclosed, cartridge filter) (Millipore, 0.22µm). Up to 10 litres of water was filtered from each depth, with attention to maximum flow rate. GF/F filters were folded and placed in 1.5ml eppendorf tubes. Excess water from the Sterivex filters was removed by pushing air through with a 50ml syringe. All samples were frozen and stored at -80 °C.

Comments: Some of the Sterivex filters appeared to tear when air was pushed through using a syringe, to remove excess water. The filters appeared intact before this process. The flow was reduced, in case the pressure from the flow was weakening them. Less pressure was applied when using the syringe, but still some of the filters appeared to tear. E-mail was sent to Markus Moeseneder to discuss the issue. He suspected a quality issue with these filters as he had not witnessed this problem before, but believes extraction should be ok as the filters were intact during filtration.

Table 3.2.1. Station list for CTD prokaryotic samples.

Station #	Date	Latitude (N)		Longitude (W)		Max. depth (m)	Time in (GMT)	Time out (GMT)
D377_16 CTD Cast #3	10/07/2012	48	56.353	16	32.708	~4800	12:24	17:01
D377_33 CTD Cast #4	14/07/2012	49	1.3981	16	34.2395	~4814	10:30	14:45
D337_53 CTD Cast #6	22/07/2012	6	2.11	16	32	~4808	11:07	13:12

Table 3.2.2. CTD prokaryotic sample details.

Station #	Depth	Unit	Analysis order	Sample #	GF/Fs	Cartridges	Amount filtered (L)	Comments
D377_16 CTD Cast #3	10	m.a.b.	1	1	2	1	10	GF/F changed after 5L
	4729	m	1	2	2	1	10	GF/F changed after 5L, Same depth as a sediment trap
	3050	m	1	3	2	1	10	GF/F changed after 5L, Same depth as a sediment trap
	20	m	1	4	2	1	10	GF/F changed after 5L, Chl-maximum
	10	m	2	5	1	1	10	
	500	m	2	6	1	1	7.5	Jerrycan not acid washed.
	50	m.a.b. (4779 m)	2	7	1	1	10	Jerrycan not acid washed.
	25	m.a.b.	3	8	2	1	10	Double GF/F
	3000	m	3	9	1	1	10	Same depth as a sediment trap
	1000	m	3	10	1	1	8.5	
	80	m	3	11	1	1	10	
	*No sample from 100m-water lost							
D377_33 CTD Cast #4	20	m	1	12	2	1	10	GF/F changed @ 7.5L, Chl-maximum
	3052	m	1	13	1	1	10	Same depth as a sediment trap
	4750	m	1	14	1	1	10	Same depth as a sediment trap
	10	m.a.b. (4829 m)	1	15	1	1	10	
	10	m	2	16	2	1	10	GF/F changed @ 6L
	100	m	2	17	1	1	10	GF/F dropped-1/2 that touched floor removed, clean 1/2 recovered and frozen
	500	m	2	18	1	1	10	
	50	m.a.b. (4788 m)	2	19	1	1	10	
	80	m	3	20	1	1	9.5	
	1004	m	3	21	1	1	9	
	3002	m	3	22	1	1	10	
	25	m.a.b. (4813 m)	3	23	1	1	10	

*Concern over filters tearing under pressure of syringe when removing water.

Table 3.2.2. CTD prokaryotic sample details (continued).

Station #	Depth	unit	Analysis order	Sample #	GF/Fs	Cartridges	Amount filtered (L)	Comments
D337_53	10	m	2	24	2	1	10	GF/F changed @5L
CTD Cast								
#6	14	m	1	25	2	1	10	GF/F changed @5L, Chl-maximum
	100	m	2	26	1	1	10	
	504	m	2	27	1	1	10	
	80	m	3	28	1	1	10	
	1004	m	3	29	1	1	10	
	2500	m	3	30	1	1	9.5	Same depth as a sediment trap

*Not sampled to bottom (~4808 m) due to time constraints. Sampled to 2500 m with 7 sample depths

3.3 Sediment Coring - Brian Bett et al.

3.3.1 *Interpretation of soundings for water depth*

On our first visit to the Goban Spur (stns: D377-001 to 009) echo-sounding was carried out on the Precision Echo Sounder (PES) fish with the transducer depth of the EA500 (echo-sounder) set to 8.5 m. The correct transducer depth for the fish was later determined to be 22.3 m (by comparison with soundings from the hull transducer). The original recorded depths were correspondingly corrected to z+14 m. At the Porcupine Abyssal Plain, stns D377-010 and 011 were completed using the PES fish (transducer depth correctly set to 22.3 m). The PES fish winch subsequently failed and all other stns were completed by echo-sounding from the hull with the transducer depth correctly set to 5.3 m. All soundings were corrected using standard 'Method A' in the 'Carter Tables'[1] (i.e. the EA500 was operating with a fixed sound velocity profile of 1500 m/s).

Soundings in the AESA area were somewhat ambiguous as a result of the broad beam angle[2] of the echo-sounder's transducer and the abyssal hill topography. Plots of meters of wire out at bottom contact against sounding (EA500) for corer deployments in the AESA area showed substantial scatter, particularly for sites over the flanks of the abyssal hill (Fig. 3.3.1).

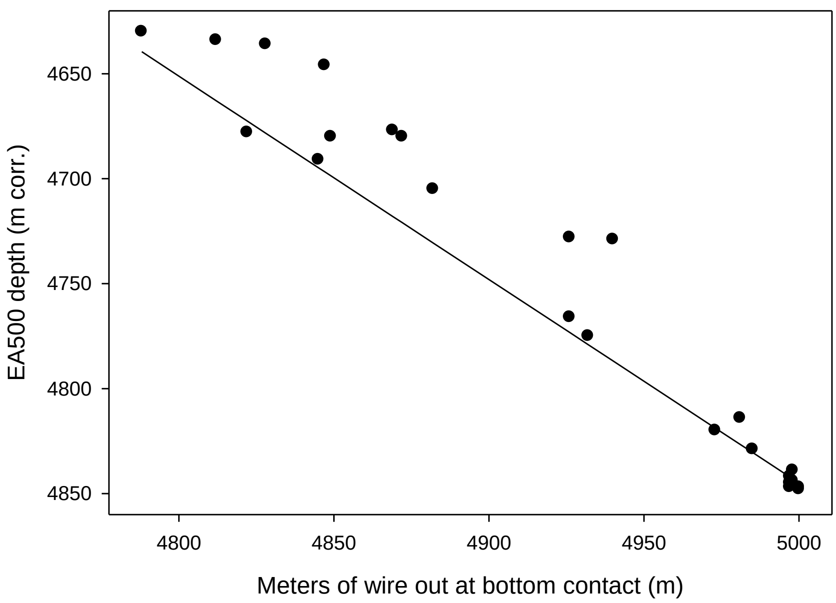

Fig. 3.3.1. Scatter plot of echo-sounder (EA500) depth against meters of wire out during corer deployments in the AESA area. The line shows the approximate relationship between wire out and water depth for the deepest sites (i.e. those most distant from / least influenced by sloping topography).

Swath bathymetry obtained during RRS *James Cook* cruise 071 (JC071) and that obtained from Autosub6000 during the present cruise was further used to assess the depth of water at the individual coring sites. The ArcGIS function 'Extract values to points' was used (with interpolation on) to derive water depths for core site positions. The relationship between

[1] Carter, D.J.T., 1980. Echo-sounding correction tables (3rd Edition). Hydrographic Department, Ministry of Defence; Taunton.

[2] Thought to be the order of 45 degrees – Dave White (NMFD) pers. comm.

JC071 swath depth and meters of wire out at bottom contact was strongly linear and compact (r^2 = 99%, Fig. 3.3.2). A similarly close relationship (r^2 = 96%) was apparent between Autosub6000 swath depth and meters of wire out (Fig. 3.3.3).

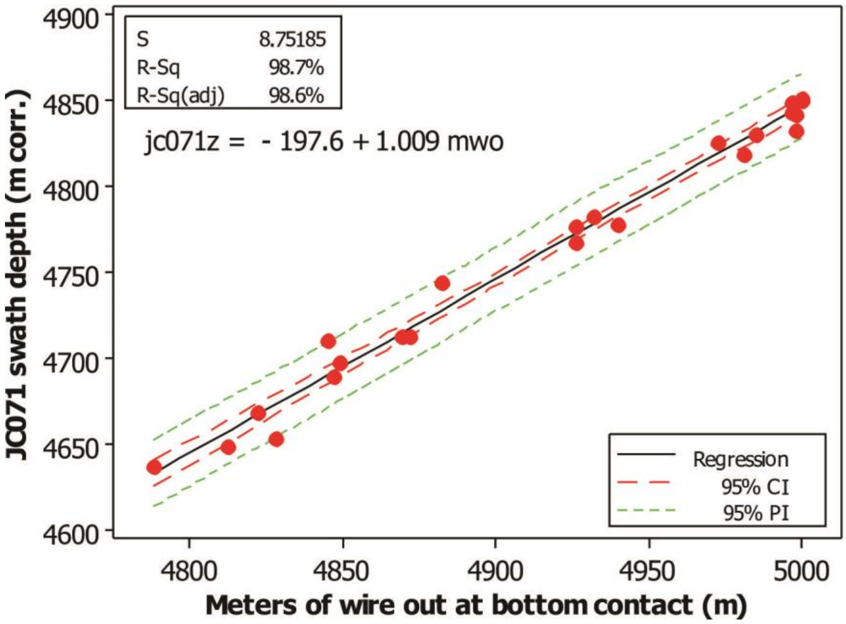

Fig. 3.3.2. Linear line fit plot of RRS James Cook cruise 071 interpolated swath depth and meters of wire out at bottom contact during corer deployments in the AESA area.

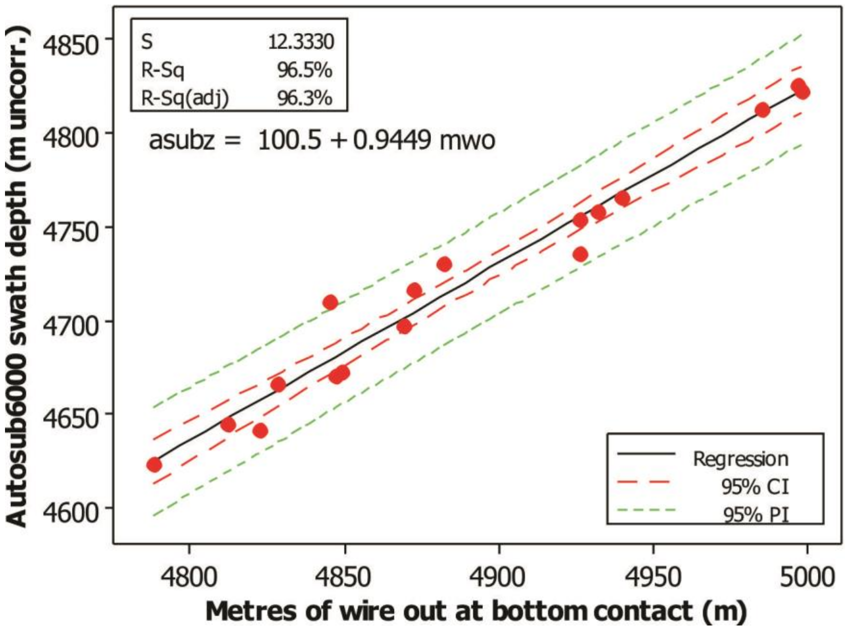

Fig. 3.3.3. Linear line fit plot of Autosub6000 interpolated swath depth and meters of wire out at bottom contact during corer deployments in the AESA area.

While there is a good linear relationship between Autosub6000 and JC071 interpolated swath depths (r^2 = 97%, Fig. 3.3.4), there is a distinct offset in absolute soundings, median offset 15 m shallow for Autosub6000. To further test this offset, 500 random points (generated by ArcGIS) were selected on the Autosub6000 swath and interpolated depth values were extracted (as above) from both the Autosub6000 and JC071 swath data. These data suggested a median offset of 20 m, with Autosub6000 reading shallow (Fig. 3.3.5). The Autosub6000 vehicle carried two pressure / depth sensors, one the vehicle depth sensor the other part of the CTD instrument package. A comparison of these two instruments (Fig. 3.3.6) also indicates an offset of c. 20 m between recorded vehicle depth (i.e. the swath datum) and recorded CTD depth.

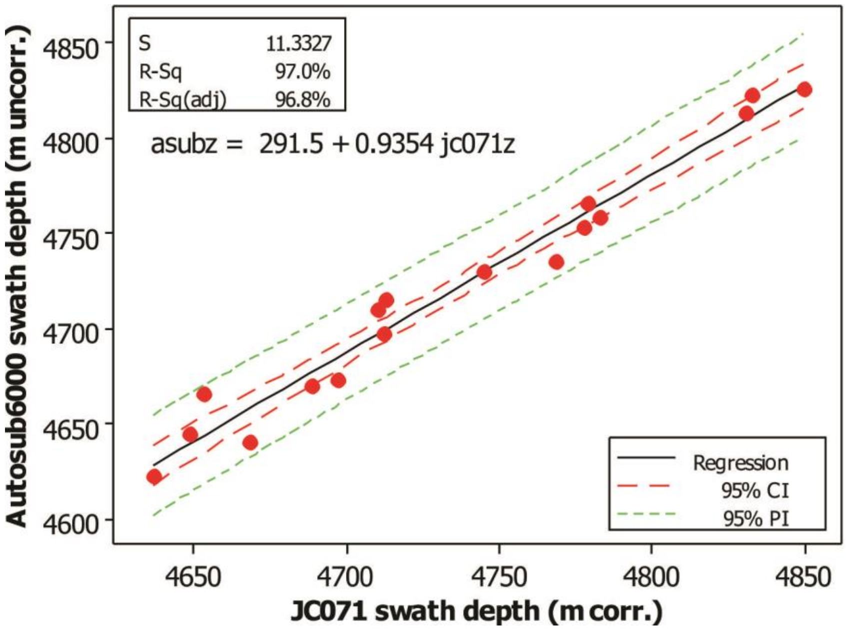

Fig. 3.3.4. Linear line fit plot of Autosub6000 interpolated swath depth and JC071 interpolated swath depth during corer deployments in the AESA area.

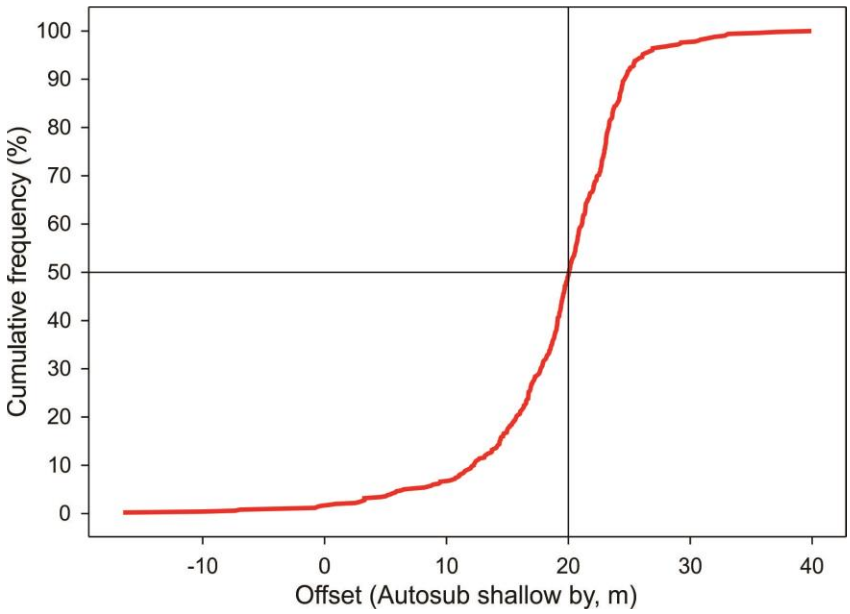

Fig. 3.3.5. Apparent Autosub6000 swath depth offset relative to JC071 swath depth, as cumulative frequency of 500 randomly selected locations.

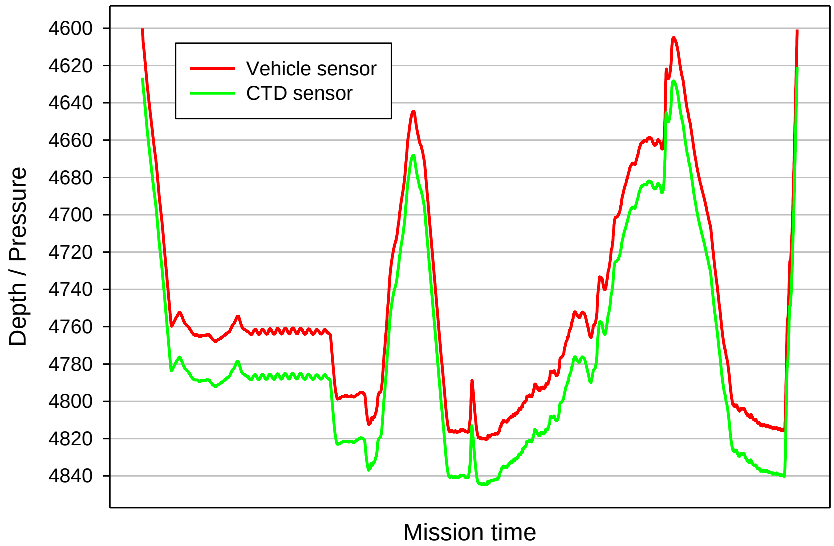

Fig. 3.3.6. Comparison of Autosub6000 pressure / depth sensors (example from near-bottom operations phase of Mission 57), showing consistent offset of order 20m.

3.3.2 *Megacoring*

The NOC-OBE Bowers & Connelly megacore was used throughout the cruise (Goban Spur; AESA area; PAP-central). It was rigged and operated in normal fashion, with minor adjustments to the ballast load and the number and type of coring units deployed. The corer generally performed well with failures of individual coring units mostly attributable to soft / low resistance sediments failing to trigger the primary mechanism. The corer was damaged during stn D377-028 as a result of it falling over at the seafloor and the main lowering bars being bent when hauling it off the seafloor. A repair of replacing the main bars got the system back in service quickly.

Goban Spur sampling

The Megacore was used during two visits to the Goban Spur (stns D377-003 to009, 7-8.VII.12; and stns D377-056 to 061, 23-24.VII.12) to a site c. 49° 36´ N 011° 51´ W at a sounding of c. 1000 m. The resultant cores were all used for an oil exposure experiment (see elsewhere in this report) with the exception of the last deployment (D377-061) that was sampled for ethanol preserved macrobenthos (metazoan and protozoan; see section 3.2 in this report for details).

PAP-central sampling

The Megacore and box core were deployed at the Porcupine Abyssal Plain Sustained Observatory standard coring area (‘PAP-central’). Three sites were selected at random positions within a 500 m radius of the nominal centre position (Fig. 3.7). Both corers were successfully deployed at each site (box core stn.s D377-044 to 046; Megacore stns D377-038, 041, 048). See Table 3.3.2 in this report for details of resultant sample processing.

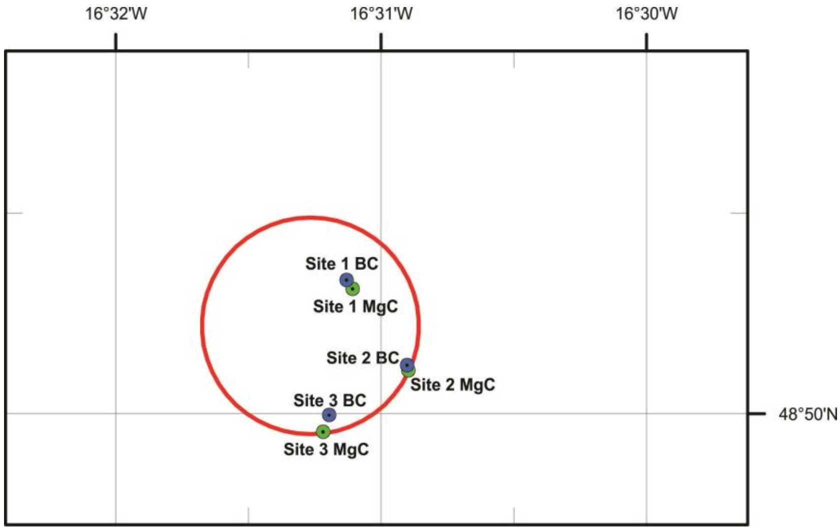

Fig. 3.3.7. Coring operations at the PAP-central site (MgC, Megacore; BC, box core). Red circle is 500 m radius from nominal centre of the Porcupine Abyssal Plain - Sustained Observatory standard coring position.

AESA area sampling

Seabed sampling in the AESA area (Fig. 3.3.8) was carried out according to a stratified random sampling design. Two criteria were applied in the selection of sampling sites, (a) randomisation within depth strata, and (b) coincidence with planned large-scale photographic survey tracks (see Fig. 3.3.9). Depth strata were in 50 m bands: (i) <4690 m, summit of abyssal hill; (ii) 4690-4740 m; (iii) 4740-4790 m; (iv) 4790-4840 m; (v) >4840 m, abyssal plain. As noted above ('interpretation of soundings' section), water depth recorded during coring operations was somewhat ambiguous as a result of the abyssal hill topography and the wide beam angle of the ship's echo-sounder. The best option for survey site depths was provided by the swath bathymetry obtained during RRS *James Cook* cruise 071. Those data were collected purposefully for the AESA area and employed an accurate sound velocity profile, and serve as a valuable standard for other sounding and depth data. Table 3.3.1 lists the measured and interpreted soundings for the Megacore deployments in the AESA area.

Table 3.3.1 also lists other possible factors that may be relevant to the subsequent analysis of data from the AESA area Megacore samples, primarily related to a topographic interpretation of the area (see Figs. 3.3.10 and 3.3.11). This interpretation was based on a subjective assessment of the JC071 and Autosub6000 swath bathymetry datasets. The 4840 m contour of the JC071 data provides a useful baseline for the stratified random sampling survey, separating abyssal plain from abyssal hill terrain, and also appears to illustrate debris flow run out areas (note for example the lobate outline in the SSW and ESE quadrants of the abyssal hill). The detailed Autosub swath, particularly when viewed with hillshading, revealed extensive slope failures, as headwall scarps and 'blocky' debris flows. Some isolated ('rafted') sediment blocks are also apparent on both the JC071 and Autosub6000 swath.

Megacore sites within slide scars or debris flows have been categorised as 'disturbed' in Table 3.3.1. When these landslides occurred is unknown, whether their impact could still influence the sampled fauna remains to be seen.

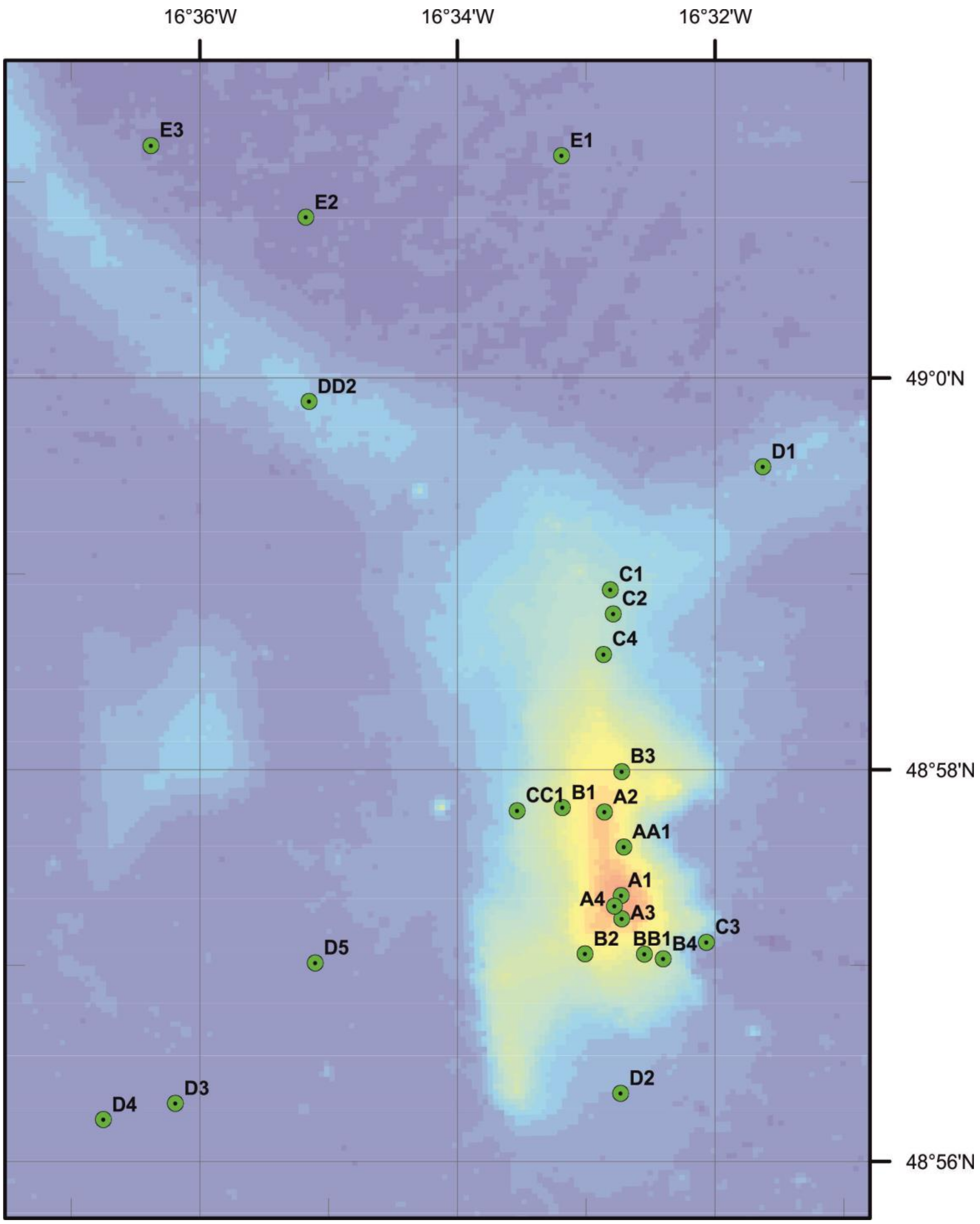

Fig. 3.3.8. AESA study area, shown with JC071 swath as basemap and general locations of Megacore deployments during RRS *Discovery* cruise 377/8.

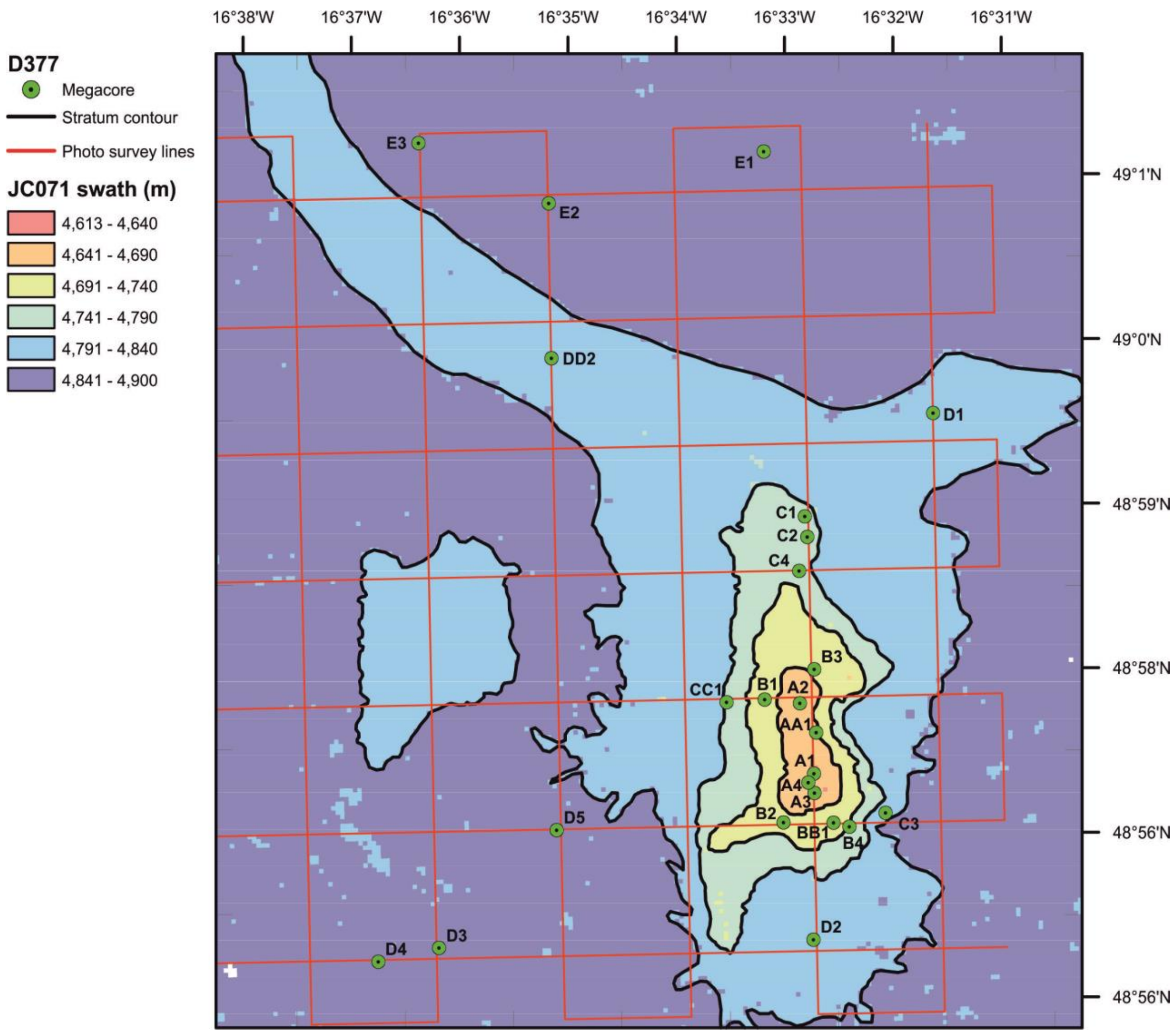

Fig. 3.3.9. AESA study area, shown with 50m depth strata boundaries (JC071 swath), planned large-scale photo-survey lines and Megacore sample sites during RRS *Discovery* cruise 377/8.

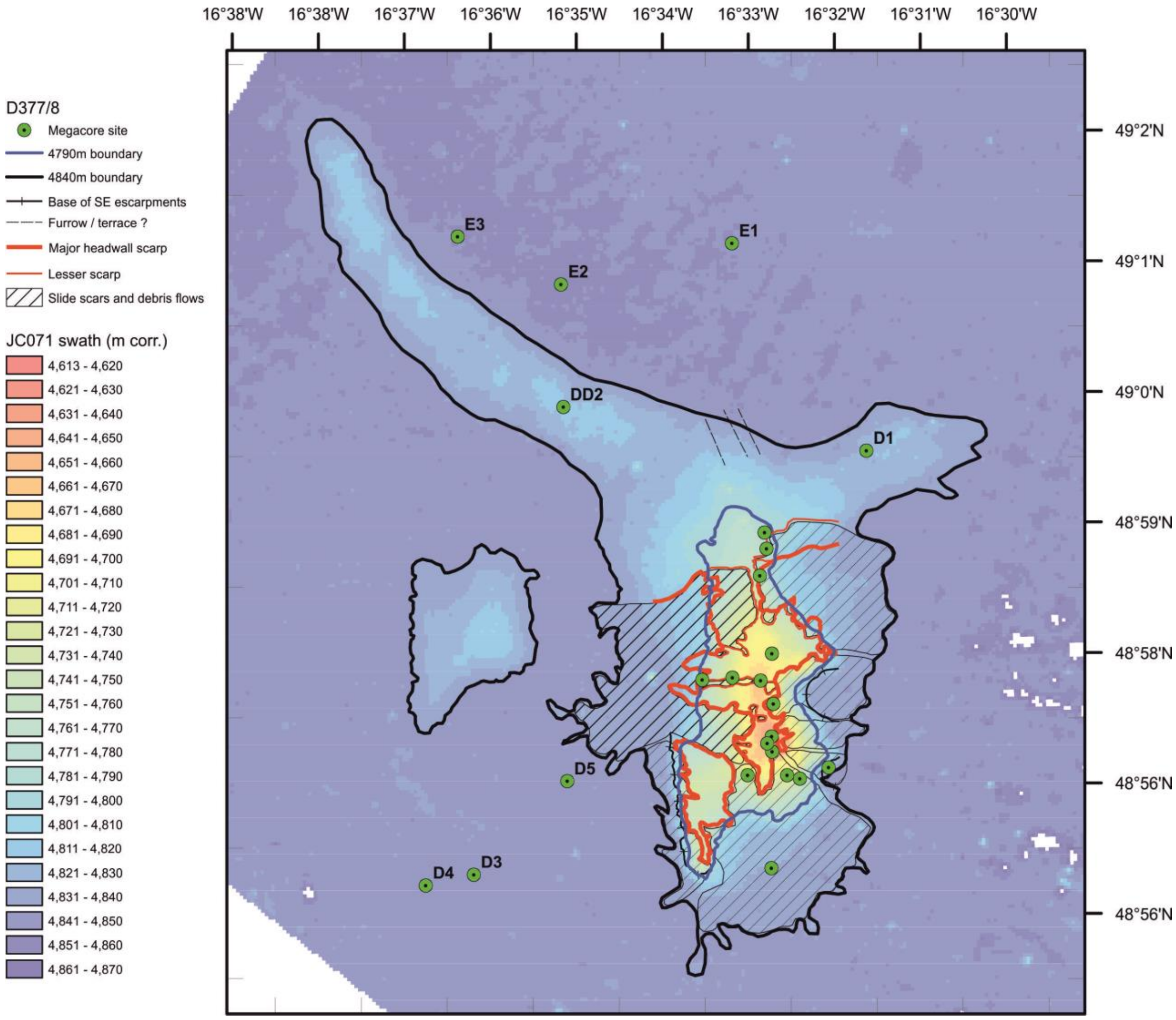

Fig. 3.3.10. Interpreted map of the AESA study area, showing Megacore sample sites relative to interpreted topography.

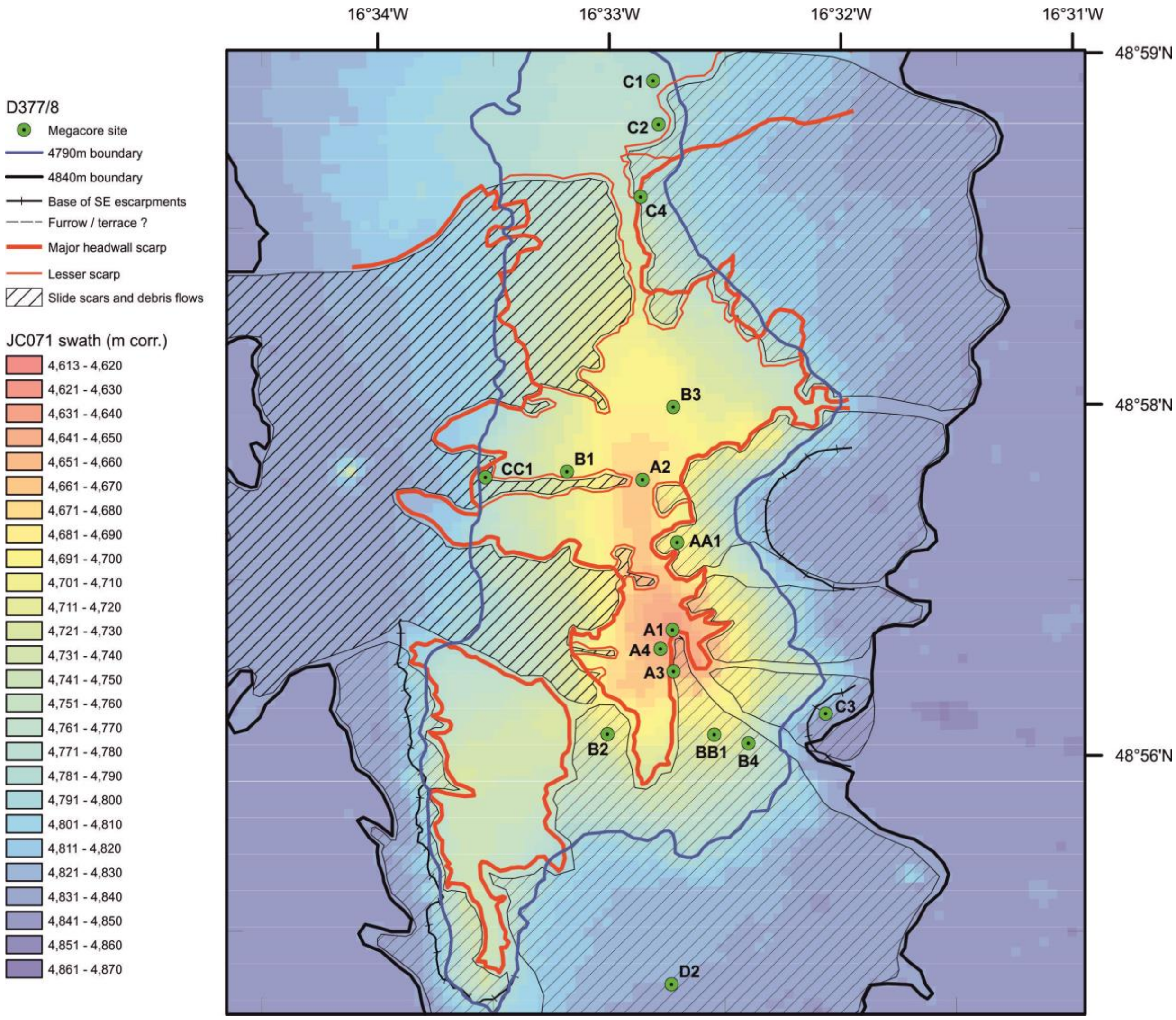

Fig. 3.3.11. Interpreted map of the AESA study area, showing Megacore sample sites relative to interpreted topography (enlargement of summit).

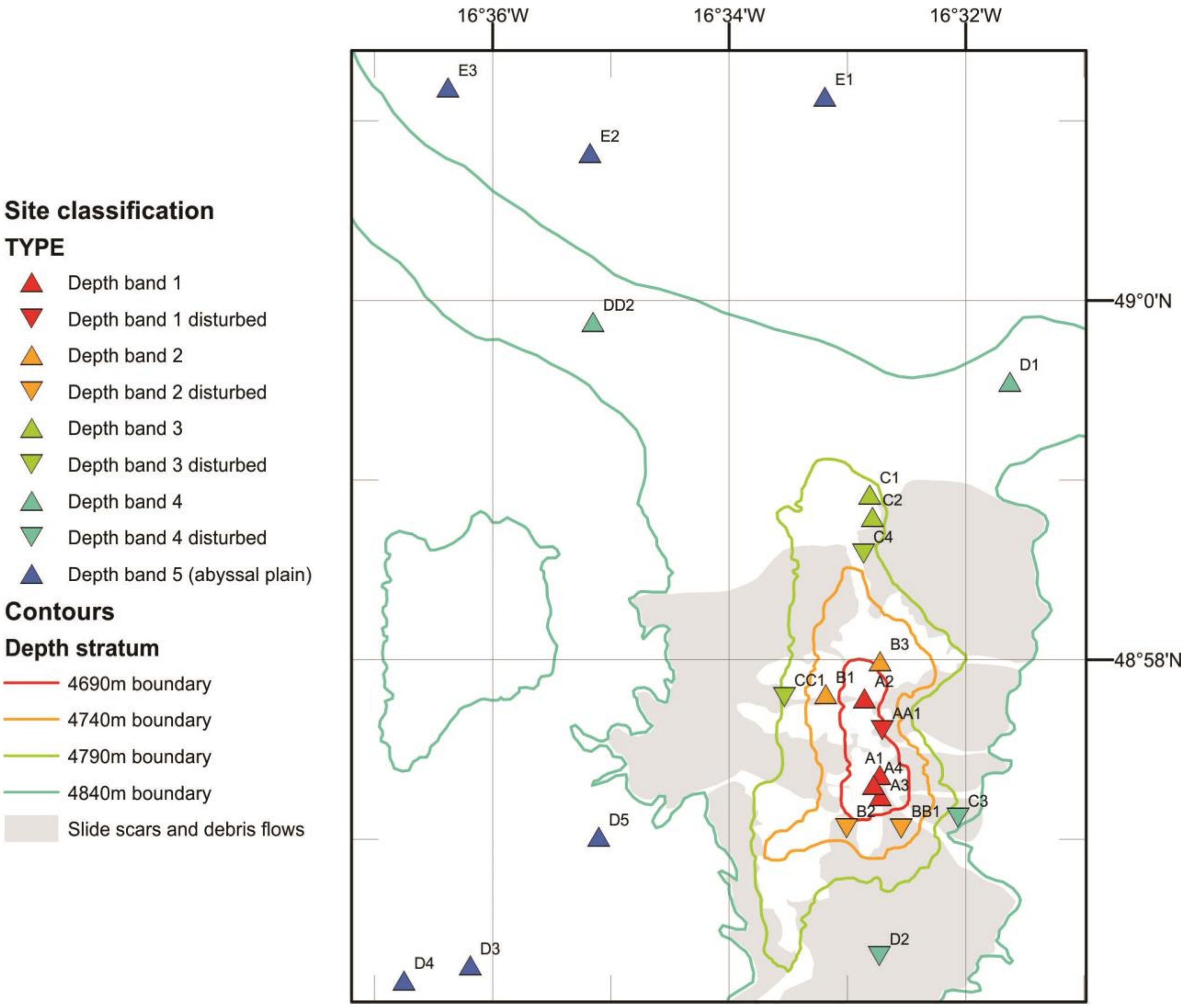

Fig. 3.3.12. AESA study area Megacore sample sites shown by depth stratum classification and seabed disturbance type (disturbed – located within slide scar or debris flow areas; see Fig. 3.3.11).

Table 3.3.1. AESA area Megacore stations / sites – depth strata (colour coded) and other classifications. (Physiography: abyssal plain / abyssal hill; Distance to elevated topography: horizontal range to hill's 4840m contour for abyssal plain sites; Depth band, 50m-intervals colour coded [based on hand-contouring of JC071 swath illustrated in Fig. 3.3.9]; Disturbed seabed, 0 – apparently undisturbed, 1 site located in slide scar or debris flow; JC071 swath, depth of site as interpolated from JC071 swath data; JC071-MWO adjusted, depth of site calculated from relationship between interpolated JC071 swath depth and MWO at bottom contact).

		Measured data		Visual interpretation				Interpreted sounding	
Station	Site	MWO at bottom contact (m)	Sounding (m corr.)	Physio-graphy	Rough distance to elevated topography (m)	Depth band	Disturbed seabed	JC071 swath	JC071-MWO adjusted
D377-029	A1	4788	4630	Hill	0	1	0	4637	4633
D377-032	A4	4812	4634	Hill	0	1	0	4648	4658
D377-030	A2	4822	4678	Hill	0	1	0	4668	4668
D377-031	A3	4828	4636	Hill	0	1	0	4653	4674
D377-036	AA1	4847	4646	Hill	0	1	1	4689	4693
D377-035	BB1	4845	4691	Hill	0	2	1	4710	4691
D377-027	B3	4849	4680	Hill	0	2	0	4697	4695
D377-024	B1	4869	4677	Hill	0	2	0	4712	4715
D377-025	B2	4872	4679	Hill	0	2	1	4713	4718
D377-015	C2	4926	4766	Hill	0	3	0	4777	4773
D377-023	C4	4926	4728	Hill	0	3	1	4768	4773
D377-014	C1	4932	4775	Hill	0	3	0	4782	4779
D377-037	CC1	4940	4729	Hill	0	3	1	4778	4787
D377-011	D1	4973	4820	Hill	0	4	0	4826	4820
D377-040	DD2	4981	4814	Hill	0	4	0	4819	4828
D377-013	D2	4985	4829	Hill	0	4	1	4830	4832
D377-022	C3	4998	4844	Hill	0	4	1	4832	4845
D377-010	E1	4997	4847	Plain	2400	5	0	4849	4844
D377-019	D3	4997	4845	Plain	2400	5	0	4844	4844
D377-020	D4	4997	4842	Plain	3000	5	0	4843	4844
D377-021	D5	4998	4839	Plain	600	5	0	4842	4845
D377-017	E3	5000	4847	Plain	600	5	0	4851	4847
D377-018	E2	5000	4848	Plain	900	5	0	4851	4847

Initial observations

Megacore sample processing (Gooday et al.) – A total of 210 tubes were recovered which were processed for macrofauna foraminifera, prokaryotes, biomarkers and sediment grain size distribution (Table 3.3.2). Megacorer profiles were routinely photographed during operations in the AESA study area and at the PAP central location. Figs 3.3.9-3.3.12 document the core profiles from the AESA area, grouped by depth stratum (see Table 3.3.1). Notable profiles were: (a) site A4 which appeared to show considerable disturbance / disruption to its layering; (b) site C4 which showed a very sharp transition to consolidated white clay at the base of the core; (c) sites D3 and D4 which had a three-layer profile essentially identical to that encountered in the PAP central area (see Fig. 3.3.13 - 3.3.15), with site D5 somewhat variant; and (d) sites E1-E3 which had homogenous profiles of unconsolidated sediment very similar to that of site F1, as sampled during RRS *James Cook* cruise 062.

We aimed to collect replicate samples for macrofauna fixed in formalin (faunal analyses), meiofauna (foraminifera), prokaryotes, sediment granulometry and biochemical parameters. We did this using a 7+3 arrangement (7 x 10 cm diameter tubes + 3 x 7 cm tubes), but with variations depending on core recovery rates. Each core tube was numbered for its position on the corer and position recorded. The sample categories were processed as follows:

Foraminifera: Small multicore samples were sliced into the following layers: 0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0 cm, then 2-3, 3-4, 4-5, 5-6, 6-7, 7-8, 8-9, 9-10 cm. Each layer was placed in a 500 ml plastic Nalgene jar and fixed with 10% buffered formalin.

Prokaryotes: Disposable gloves were worn throughout the core-cutting process. Megacore samples were sliced into the following layers: 0-1, 1-2, 2-3 cm, then 3-5, 5-10, 10-15 cm. The edges of each layer were first trimmed with a knife before being placed in a plastic zip-lock bag. Between each slicing event, the sediment was first washed off the plate, knife and cutting ring with water. All surfaces that could come into contact with the inner part of the core (cutting plate, knife, gloves) were rinsed with ethanol. The slices from one core were placed inside a larger zip-lock bag and put in the -80° freezer.

Biomarkers: Megacore samples (Table 4.10.3) were sliced into the following layers: 0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0 cm, then 2-3, 3-4, 4-5, 5-6, 6-8, 8-10 cm. Each slice was transferred into a labelled petrie dish lined with muffled foil, maintaining slice integrity as far as possible. The rim of the petri dish were taped to secure the sample. If the petrie dish could not be closed fully, the foil was wrapped around the exposed sediment and taped in place. After each section had been sliced, the slicing plate was cleaned by washing in seawater and then rinsed with MilliQ distilled water, using awash bottle. All petrie dishes from one sample was placed in a plastic bag and stored in the -80°C freezer.

Formalin macrofauna: The top layer water was removed through a 300 micron sieve, the sieved material concentrated and washed into the 0-1 cm sampling bucket. Then, the core was sliced into 0-1, 1-3, 3-5, 5-10 and 10-15 cm layers and bulk preserved in 10 % formalin (sediment to formalin ratio 1 to 5) without sieving. Each slice went into a separate UN certified hazardous goods container as was done on JC071.

Sediment granulomtery: Cores was sliced into the following layers: 0-1, 1-3, 3-5, 5-10, 10-15 cm. Each slice was placed in a labelled plastic bag. All bags from one core was transferred into a larger plastic bag and stored in a refrigerator (not frozen) for grain size analysis.

Table 3.3.2. Breakdown of tubes available for sample processing for fauna, chemical analysis and sediment grain size distributions.

Event No.	Station	Prokaryotes	Biomarkers	Sediment grain size	Forams	Macrofauna
D377-010	E1	1	1	1	1	0
D377-011	D1	1	1	1	1	4
D377-013	D2	1	1	1	1	4
D377-014	C1	1	1	1	1	3
D377-015	C2	1	1	1	1	4
D377-017	E3	1	1	1	1	4
D377-018	E2	1	1	1	1	4
D377-019	D3	1	1	1	1	4
D377-020	D4	1	1	1	1	4
D377-021	D5	1	1	1	1	4
D377-022	C3	1	1	1	1	3
D377-023	C4	1	1	1	1	4
D377-024	B1	1	1	1	1	4
D377-025	B2	1	1	1	1	6
D377-027	B3	1	1	1	1	6
D377-028	B4	0	0	0	0	0
D377-029	A1	1	1	1	1	6
D377-030	A2	1	1	1	1	5
D377-031	A3	1	1	1	1	5
D377-035	BB1	1	1	1	1	5
D377-036	AA1	1	1	1	1	6
D377-037	CC1	1	1	1	1	5
D377-038	PAP Central 1	1	1	1	1	3
D377-040	DD2	1	1	1	1	6
D377-041	PAP Central 2	1	1	1	1	6
D377-048	PAP Central 3	1	1	1	1	5

‘Red fluff’ / ‘Red patches’ - Megacorer deployment D377-010 at site E1 returned with what appeared to be red phytodetritus on some of the core tops (see Fig. 3.3.16). Microscopic examination (Gooday) suggested it was amorphous organic matter with inclusions typical of the phytodetritus routinely encountered in the Porcupine area. Patches of red material were also noted in a number of the seabed photographs recorded during the present cruise (see Fig. 3.3.17). It is not clear whether these two observations are related. The material noted *in situ* was in discrete, dense patches, whereas the ‘red fluff’ on core tops was diffuse small flocs.

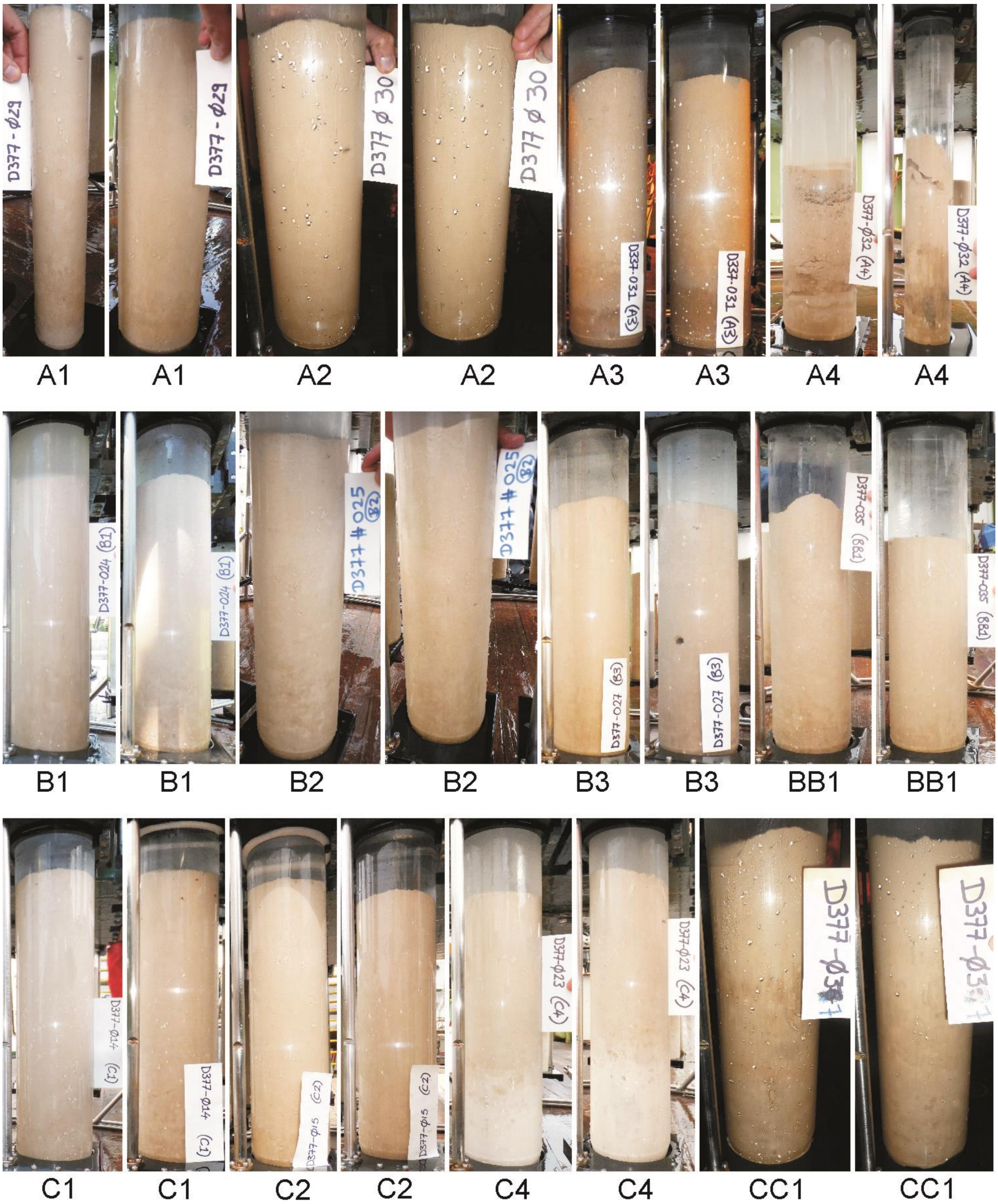

Fig. 3.3.13. AESA study area Megacore sample profile photographs (see also Fig. 3.3.8).

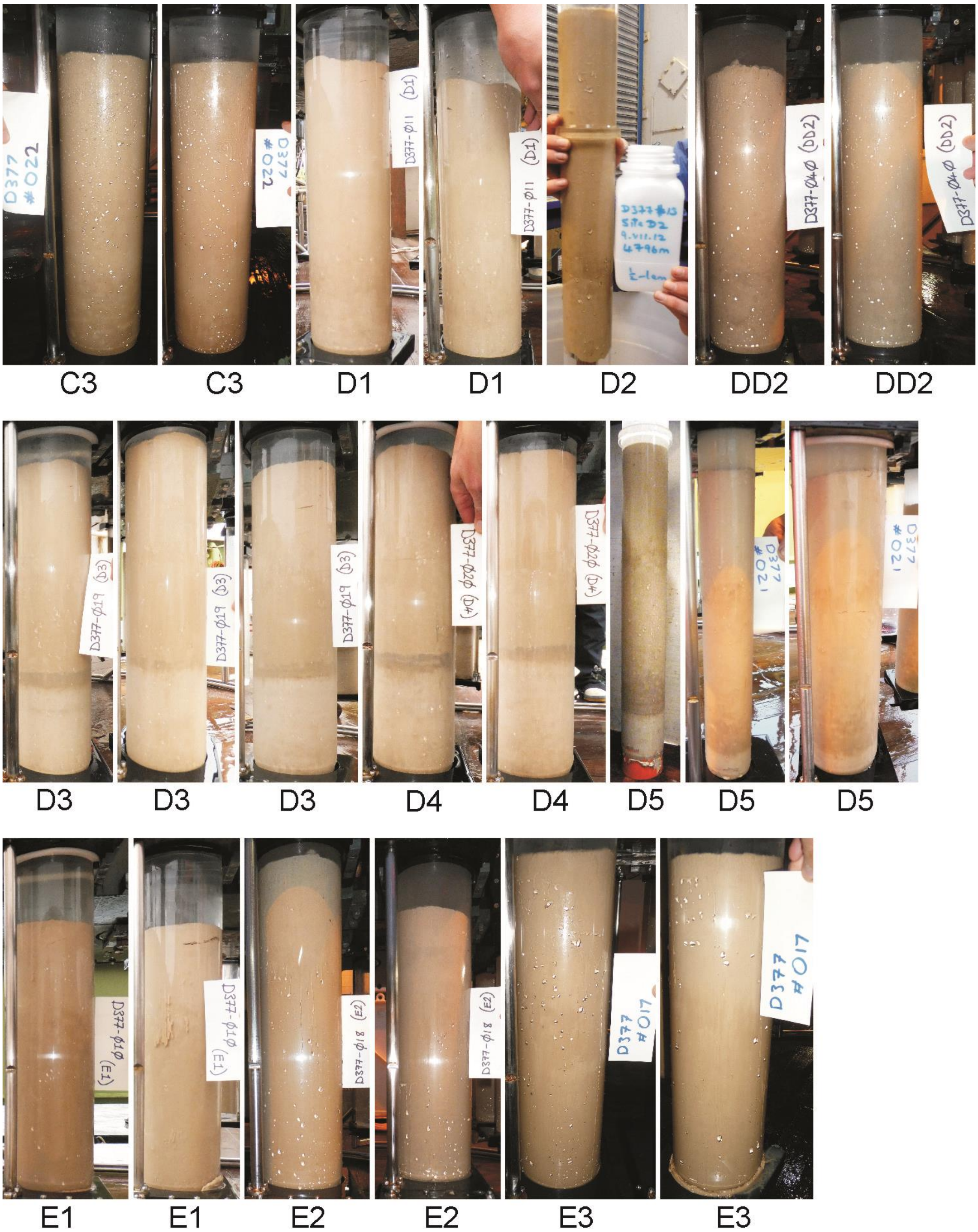

Fig. 3.3.14. AESA study area Megacore sample profile photographs (see also 3.3.8).

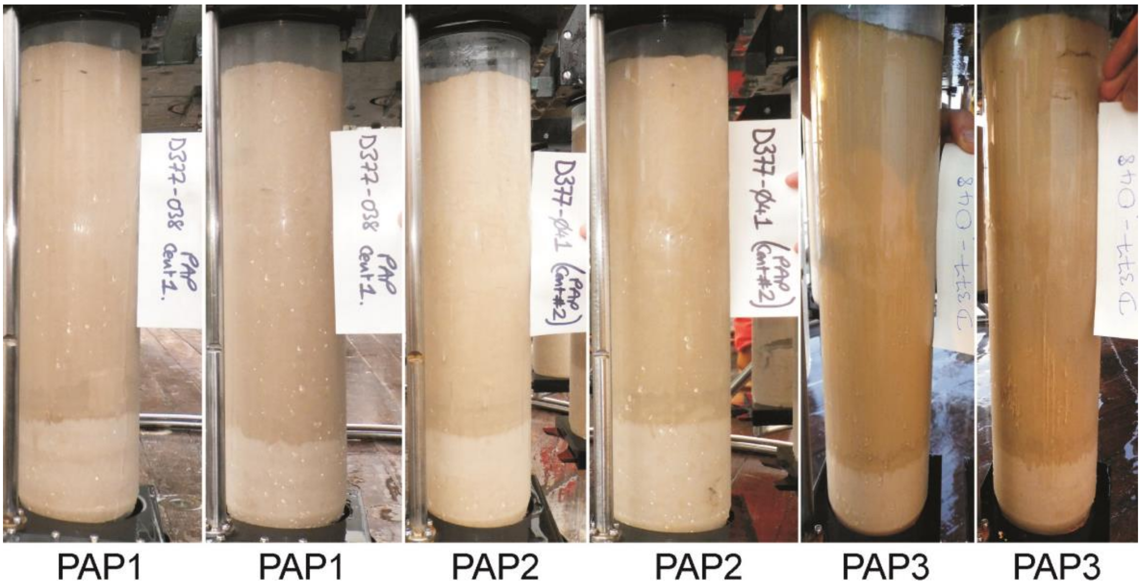

Fig. 3.3.15. PAP Central site Megacore sample profile photographs.

Fig. 3.3.16. ‘Red fluff’ noted on core tops from site E1, core tube internal diameter 10cm (stn D377-010).

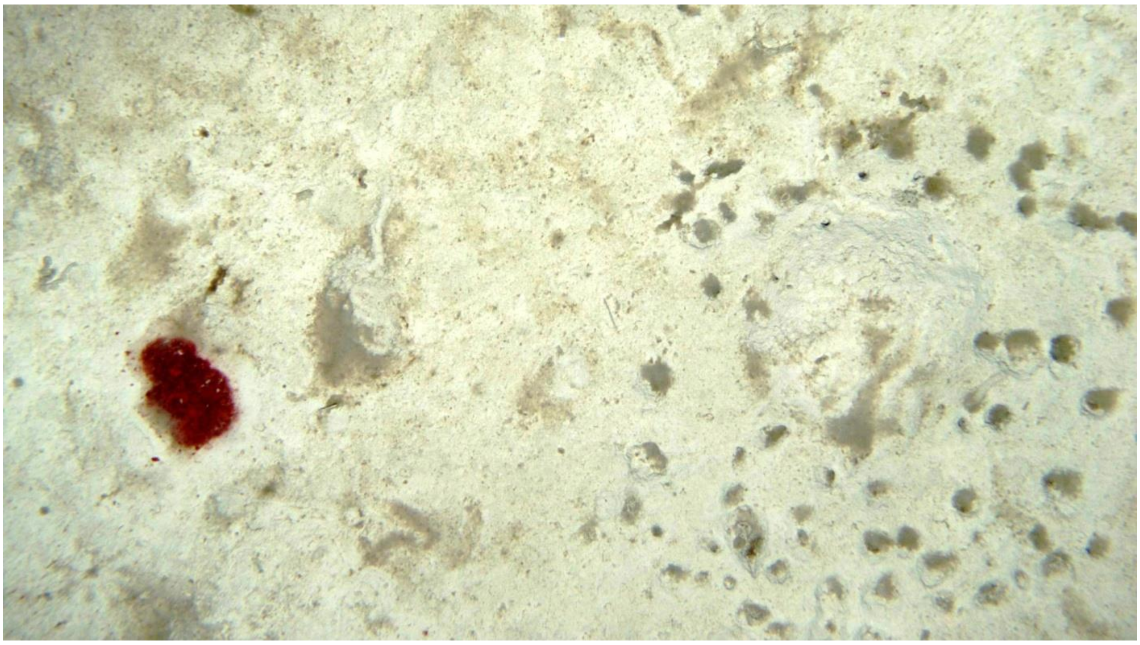

Fig. 3.3.17. 'Red patch' noted during Autosub6000 mission 51, scale width c. 1.3m at the seabed (stn D377-034; image M51_10441297_12986777325023).

Sessile fauna on stones- Andrew Gooday

Stones exposed on megacore surfaces were picked off and examined separately. At least one of the stones was clinker, but most were probably drop stones. They were strongly concentrated at the 'higher' (shallower) sites. Almost all the stones had encrusting organisms attached to their surfaces (Table 3.3.3), typically the upper surface that projected above the sediment water interface. Two brachiopods (*Pelagodiscus;* Fig. 3.3.18A) were present at Stations D377-027 and 031 and bryozoan and possible hydroid colonies at Stations 031 and 035, respectively. However, the vast majority of organisms were foraminifera, or foraminifera-like protists. The most common form, and the only one that could be assigned to a known genus, was *Telammina* sp., which comprises a very fine, delicate tubular network with associated tiny chambers (Fig. 3.3.18C). Others included flat mat-like formations (Fig. 3.3.18B), komokiaceans (Fig. 3.3.18D), simple mud domes and coarsely agglutinated domes (Figs 3.3.18E,F) and extensive networks of fine tubules (Fig. 3.3.18G). Occasional multichambed tests (e.g. trochamminaceans) were also present. Similar encrusting foraminifera are known from Pacific manganese nodules. We anticipate that the extensive bedrock surfaces observed during the SHRIMP dive will host similar organisms.

Table 3.3.3. Organisms attached to stones from Porcupine Abyssal Plain sites. Metazoans are in bold; all the other organisms are foraminifera.

Station	**Site**	**Depth**	**Core**	**Number stones**	**Attached organisms**
D377-11	D1	4820 m	?	1 (clinker – very rough surface)	Multi-chambered agglutinated test
D377-24	B1	4677 m	D	1 small stone	Mud domes with globigerina shells
D377-25	B2	4679 m	G	1 large	Large komokiacean lump; mud domes; various mud mats
			Y	1 small	Mud dome
D377-27	B3	4680 m	G1	1	*Telemmina*
			A	5	***Pelagodiscus***; grey mat; white crust
			K	4 small	Small chambers joined by delicate stolons
			H	1 large, 2 small	Network of fine tubes; chain-like formation of chambers
D377-29	A1	4630 m	Q	2 large, 3 medium, 7 small	*Telammina;* Cluster of circular mud patches; flat mat of wide grey tubes; mud domes; coarsely agglutinated domes
			N	1 large	Extensive network of narrow tubes; possible komokiacean mat
			α	1 large	3-4 mud domes giving rise to long delicate tubes; *Telammina;* flat mat of wide grey tubes
D377-31	A3	4636 m	X	1 very large, 2 small	Very little on large stone. Small stones with nice domed komokiacean; various smaller domes; organic dome; *Telammina*
			A	4 large, 2 small orange	**Bryozoan**; extensive network of fine tubes; grey mat-like formation; mud domes; komokiacean dome; brown tubes; coarsely agglutinated domes
			M	1 big stone	***Pelagodiscus****;* remains of serpulid tube; grey mat;
			Q	2 small brown stones	Mud dome; *Telammina;* coarsely agglutinated dome; trochamminid
D377-32	A4	4634 m	?	1 black/orange	*Telammina;* mud domes
D377-35	BB1	4691 m	K	1 black, 2 orange, 1?clinker	*Telammina*; komokiacean-like lump (lobed); small chambers joined by delicate stolons; small volcanoes
			T	2 black	**?Hydrozoan**; mud dome; komokiacean mat; coarsely agglutinated domes; *Telammina*; small volcanoes
			?	1 black	Mat; *Telammina;* mud domes
			V	2 small brown	Diffuse coating with mud domes; white dome with large agglutinated grains
D377-37	CC1	4729 m	V	2 small	Domes with quartz grains and glob shells
			G1	1 small	Dome with glob shells; possible komokiacean mat

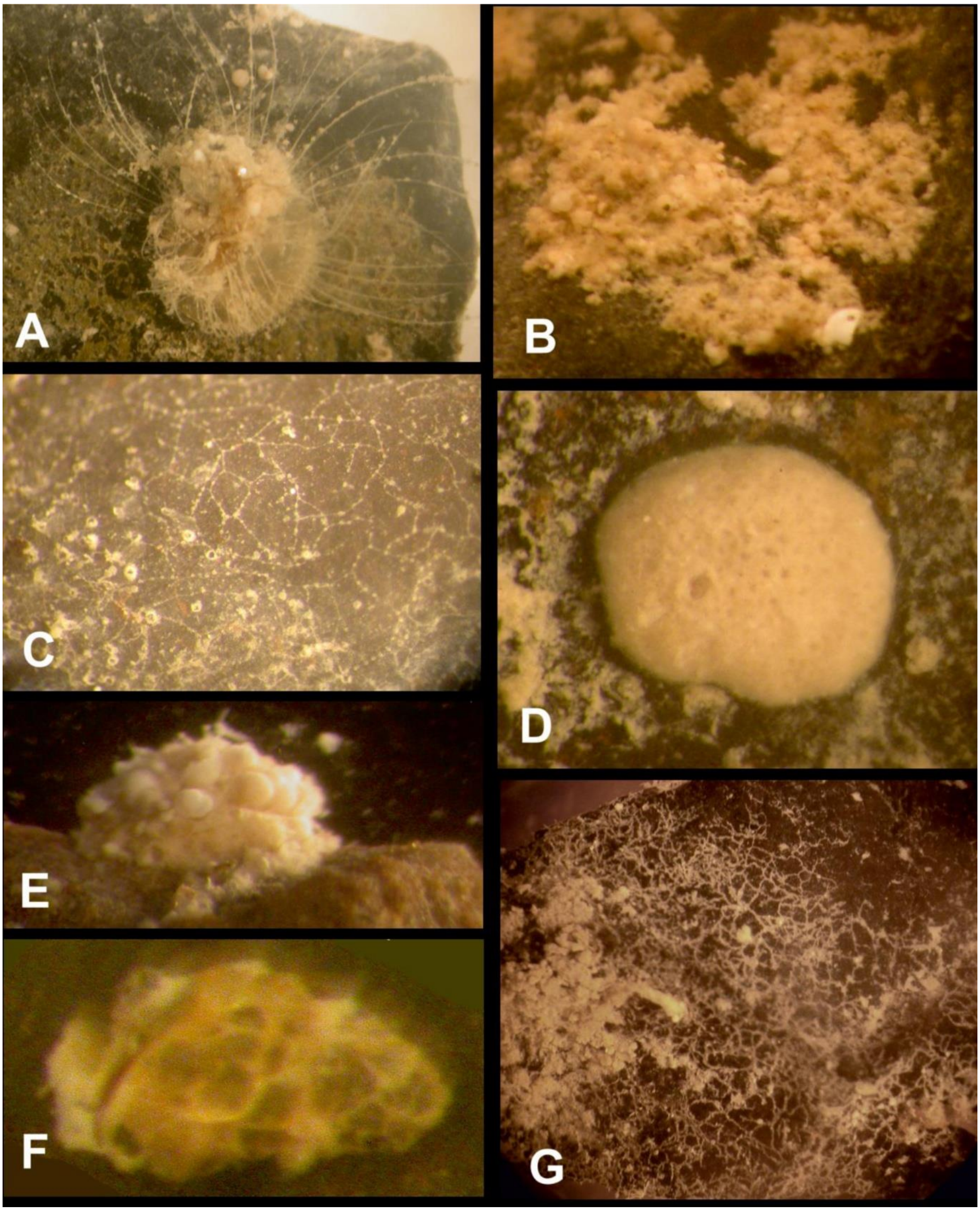

Fig. 3.3.18. Organisms attached to stones at the PAP. A) Brachiopod (*Pelagodiscus* sp); B) mat-like encrustment; C) *Telammina* sp.; D) dome-like komokicean; E) Dome incorporating globigerinacean shells; F) coarsely agglutinated dome; G) Network of tubules.

3.3.3 Box coring

An NMFD-supplied USNEL-type box core was also used during the cruise (at PAP-central only). It was rigged and operated in standard fashion (with penetration limiters fitted for all deployments). The first deployment, stn D377-042, failed as a result of the corer not triggering at the seabed. This was determined to have been caused by a too heavy gauge of wire having been used as a pre-triggering safety measure on the trigger mechanism.

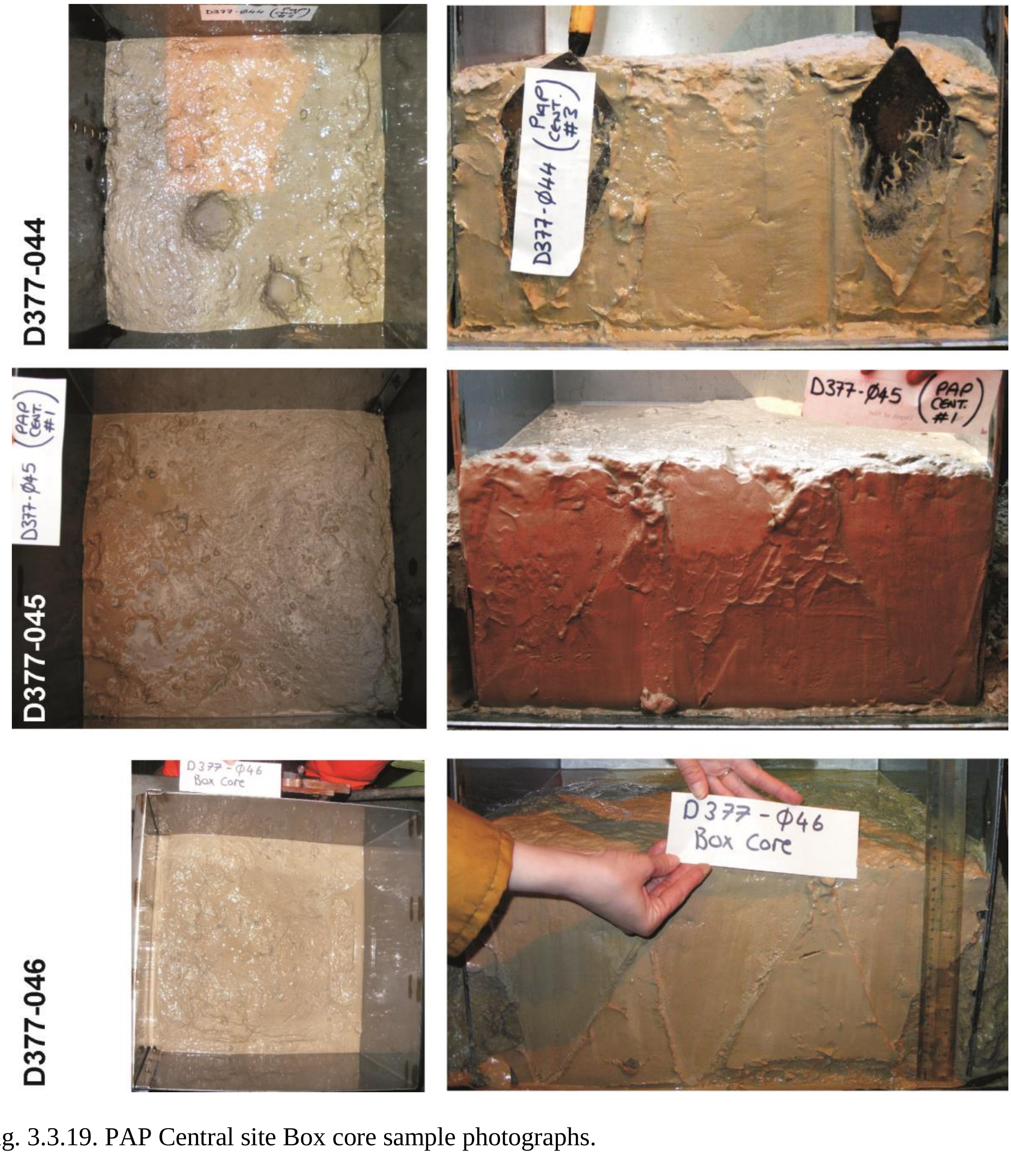

Fig. 3.3.19. PAP Central site Box core sample photographs.

Box corer sampling processing (Laguionie-Marchais et al.): At PAP central, we collected 3 replicate samples for macrofauna. The top layer water was removed through 300 micron sieve and the sieved material concentrated and washed inside the 0-1 cm sampling bucket. Then, the core was sliced into 0-1 cm, 1-3 cm, 3-5 cm layers. The 0-1 cm, 1-3 cm, 3-5 cm layers and sieved and preserved in 10 % Formalin in a ratio of ~1 to 5 (sediment to formalin). Samples were transported to the Natural History Museum (NHM) where there will be sorted to major macrofaunal groups and polychaetes will be identified to species level using morphological methods.

3.4 *Seabed High Resolution Imaging Platform* (SHRIMP) - Daniel Jones

SHRIMP (Seabed High-Resolution IMaging Platform) is a towed camera platform equipped with two video cameras (Forward-looking Bowtech Aquatech L3C-650 colour video camera and vertically-mounted Insite Pacific Pegasus colour video camera) and a stills camera system (Imenco SDS-1210).

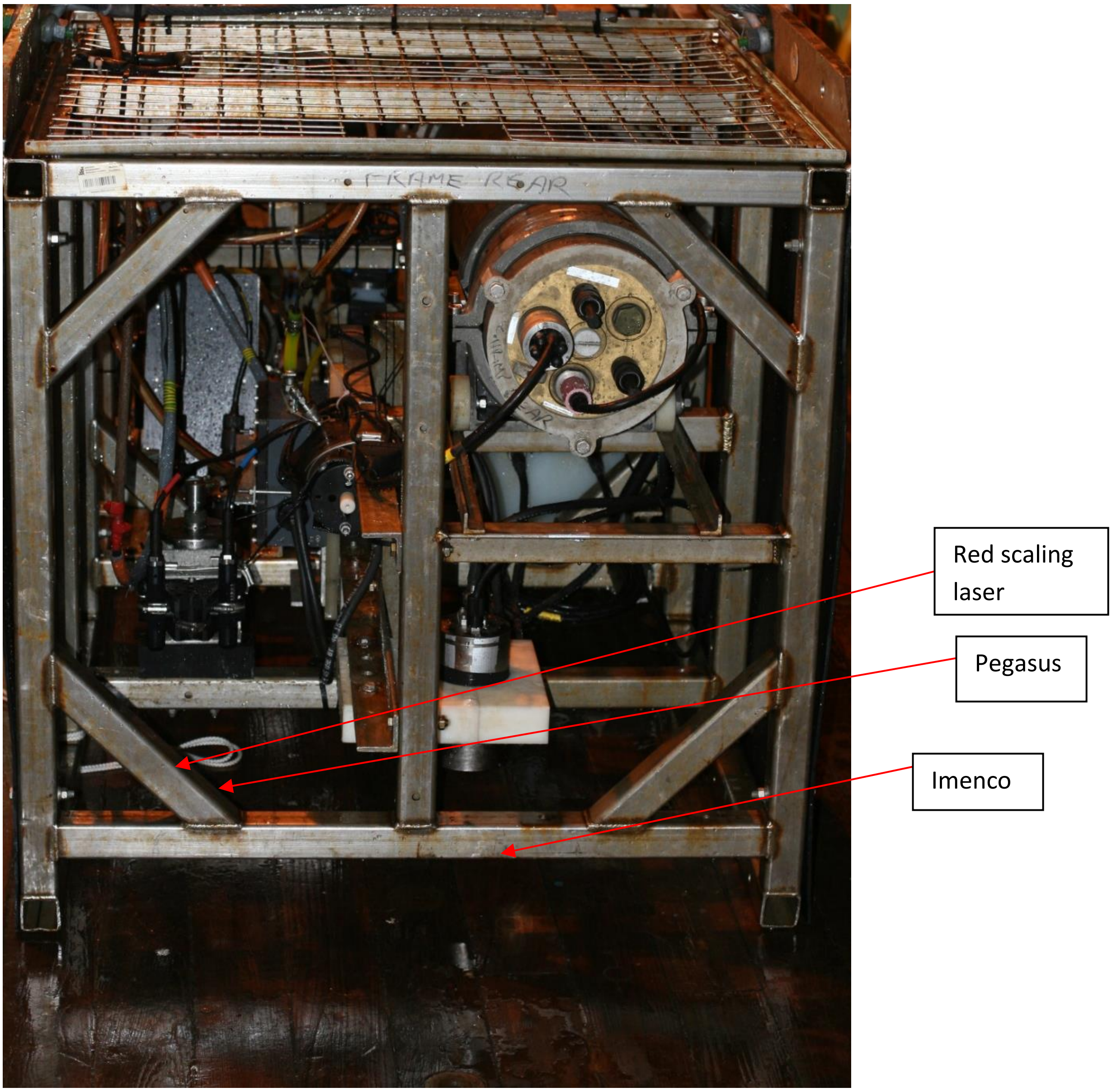

Figure 3.4.1: Photo of the back of SHRIMP showing vertical Imenco stills camera and vertical Pegasus video camera with lasers attached.

The forward looking Bowtech camera was at an angle of 34° from the horizontal. The vertically mounted Pegasus video camera has two parallel red lasers mounted on the case 100 mm apart. There is a green laser mounted at the front of SHRIMP (213 cm from the centre of the laser to the centre of the stills camera; 179 cm from the centre of the laser to the centre of the downward looking video) pointing back towards the stills camera at an angle of 51° from the horizontal. Using trigonometry, this means that the green laser lined up with the red lasers at 2.22 m altitude. SHRIMP had a weight (136 x 108 mm in size) on 1.5 m of white rope attached near the video camera to act as an altitude guide for the winch drivers to help fly the vehicle. SHRIMP is also equipped with an altimeter and a Paroscientific Digiquartz pressure sensor that are logged on the surface. Unfortunately, although we had an Ultra-Short Baseline Navigation (USBL) beacon for navigation of SHRIMP, the USBL pole on the RRS *Discovery* was damaged and it was not possible to extend the pole to monitor the USBL beacon.

Camera Setup

The video images collected by SHRIMP are transmitted real-time back to the vessel (via fibre-optics) and recorded on JVC SR-DVM700 video decks. The Pegasus video was recorded on mini-DV cassette (SP mode) and the Bowtech recorded on DVD (XP mode). The Imenco stills camera has a low-resolution video feed to the surface to allow for framing the shots, but images were stored on the 2GB memory card on the camera. The Imenco camera could be controlled on the surface using a computer Graphic User Interface (GUI) via a RS232 connection. The Imenco camera was set up using the following settings:

Mode: Auto; Flash: On; Macro: off

Table 3.4.1. Imenco camera menu settings

Setting	Value
Focus	3m
Frame size	5MP (estimated 548 frames total)
Steady Shot	Off
Sharpness	0 (normal)
Contrast	0 (normal)
Red eye	Off
Flash level	±0 (normal)
White balance	Flash white balance
EV	-2
ISO	Auto
Colour Mode	Normal
Rec Mode	Normal

The intervalometer (on the GUI) was set to 20 second interval between photographs.

Imenco Camera Details

Table 3.4.2. Angle of view in water (degrees) calculated with test image.

	Angle in degrees
Vertical	29.75
Horizontal	38.90

Pegasus Camera Details- The Pegasus camera was fully zoomed out during the SHRIMP deployment (i.e. wide angle).

Table 3.4.3. Angle of view in water (degrees) from the manual.

	4.1mm Wide Angle	73.8mm Telephoto
Vertical	37	2.0
Horizontal	48	2.7
Diagonal	58	3.3

Bowtech camera details - Fixed focus and zoom wide angle lens

Table 3.4.4. Angle of view in water (degrees)

	Fixed wide angle
Vertical	51.4
Horizontal	39.8
Diagonal	65 (from manual)

Vertical and horizontal angles of view estimated from image proportions (752 (h) x 582 (v) PAL) and diagonal angle of view (in water from manual – 2.9 mm lens).

Deployment details - For the SHRIMP runs, the vessel was aiming to move at 0.5knots over the ground. SHRIMP was lowered at 50m/min with pauses for winch checks every 1000 m. The ship's starting position was around 1km before the start point of the proposed line. The ship started moving (at survey speed) towards the start point when SHRIMP was at 3000 m depth. The SHRIMP line was ended when we estimated that SHRIMP had reached the end of the planned survey line.

Table 3.4.5. SHRIMP Deployment overview.

Station Number	Start Time	Start Lat	Start Long	End Time	End Lat	End Long
D377-051	21 July 2012 16:49	48° 57.041 N	016° 34.072 W	21 July 2012 21:50	48° 57.067 N	016° 31.484 W

Positions and time refer to time on the seafloor. Positions are approximate positions of the vessel.

Table 3.4.6. Detailed notes on deployment D377 - 051.A transit across hill feature carried out on 21 July 2012. The times are the same as Techsas data.

Time	Event
16:48:40	SHRIMP on Seafloor
16:49:00	All decks recording (Pegasus on mini-DV; Imenco and Bowtech on DVD). Tape/DVD #1
16:56:20	Moved off bottom as forward lights not working
17:04:00	Recycle power on vehicle. This stopped the Imenco and Bowtech recording (but not the Pegasus)
17:05:17	Power up again
17:05:30	Start Bowtech DVD #1 again (same disc, new chapter)
17:07:54	Time on Pegasus video 00:19:00
17:09:30	Downward lights on
17:10:04	Imenco camera on
17:11:00	Cycle power to Imenco
17:11:57	Start recording Imenco DVD #1 again (same disc, new chapter)
17:18:21	Start taking stills pictures on Imenco camera every 20 seconds.
17:20:13	Time on Pegasus video 00:31:19
17:20:33	Time on Bowtech video 00:15:00
17:20:58	Time on Imenco video 00:09:00
17:21:38	Time on Pegasus video 00:32:44
17:40:15	Rock in forward camera
17:42:13	Contact with rock
17:45:15	Rock
17:47:00	Rock
17:50:17	Pegasus DV #1 stop
17:50:27	Pegasus DV #2 start
17:52:54	Sloping sediment bottom
17:55:31	Bowtech DVD #1 stopped
17:57:19	Bowtech DVD #2 started
17:59:04	Imenco DVD #1 stopped
17:59:50	Imenco DVD #2 started
18:01:54	Sloped seabed
18:10:40	Flat seabed
18:23:04	Time on Imenco DVD #2 00:23:12
18:23:23	Time on Bowtech DVD #2 00:26:05
18:23:32	Time on Pegasus DV #2 00:33:00
18:48:32	Pegasus DV #2 stopped
18:48:53	Pegasus DV #3 start
18:57:37	Bowtech DVD #2 stopped
18:58:24	Bowtech DVD #3 start
18:59:02	Imenco DVD #2 stopped
19:02:26	Imenco DVD #3 start
19:05:43	Time on Pegasus DV #3 00:16:49
19:05:57	Edge of seabed feature

Table 3.4.6 (continued). Detailed notes on deployment D377 - 051.A transit across hill feature carried out on 21 July 2012. The times are the same as Techsas data.

Time	Event
19:07:05	Time on Bowtech DVD #3 00:08:41
19:07:22	Time on Imenco DVD #3 00:04:52
19:48:54	Pegasus DV #3 stopped (at 1:00:00 tape time)
19:49:17	Pegasus DV #4 start
20:00:24	Bowtech DVD #3 stopped (at 01:02:00 tape time)
20:01:31	Bowtech DVD #4 start
20:02:26	Imenco DVD #3 stopped (at 01:00:00 tape time)
20:03:15	Imenco DVD #4 start
20:06:04	Time on Pegasus DV #4 00:16:45
20:06:16	Time on Imenco DVD #4 00:03:00
20:06:33	Time on Bowtech DVD #4 00:05:00
20:39:30	Stills stopped (112 remaining)
20:40:25	Stills started
20:44:56	Rocks
20:46:03	Still in rocky area
20:49:20	Pegasus DV #4 stopped
20:49:51	Pegasus DV #5 start
21:03:13	Bowtech DVD #4 stopped
21:03:19	Imenco DVD #4 stopped
21:03:46	Bowtech DVD #5 start
21:04:23	Imenco DVD #5 start
21:07:33	Time on Pegasus DV #5 (00:17:40)
21:08:04	Time on Imenco DVD #5 (00:03:40)
21:07:46	Time on Bowtech DVD #5 (00:04:00)
21:49:55	Pegasus DV #5 off (01:00:00)
21:50:20	Imenco DVD #5 off (00:45:30)
21:50:20	Bowtech DVD #5 off (00:46:21)
21:51:59	End of run, haul SHRIMP at 10 m/min, increasing to 50m/min
21:54:11	Time on SHRIMP logger clock 21:53:30 on 22nd July
21:54:30	SHRIMP power off
23:45	SHRIMP on deck

Data management

The SHRIMP DVD data was saved from the DVDs onto the QNAP drives with text readme files containing the disc labels. The DV tapes have not been processed and were digitised back at NOC. A copy of the Pegasus DV tapes was made onto DVD (with associated loss in resolution) and this has been copied onto the QNAP drives.

The SHRIMP and ship (including the techsas and CLAM winch data) data files were also saved as raw files to the QNAP drives. The ship, winch and SHRIMP data files were all misaligned in time, making comparison very difficult. A custom Matlab script was written (by DJ) to sample the data (or interpolated data) from all three sources every 10 seconds. These were then combined to one master file which was also saved to the QNAP drive (alldataSHRIMPrun.xls).

Navigation and positioning

The SHRIMP track was planned to go across the large hill feature that has been the focus of this cruise (Fig. 3.4.2). The SHRIMP track (Fig. 3.4.3) corresponded with the topography predicted from the Autosub bathymetry.

In many towed-camera platform studies the position of the gear on the seafloor is calculated from ship's navigation and an assumed layback, calculated using Pythagoras' rule from the platform's depth sensor and the ship's wire out reading. By comparing the ship and SHRIMP data streams we found that the corrected depth (from the SHRIMP pressure sensor) was between 6.39 m (at 4850 MWO) and 7.3 m (at 4700 MWO) deeper than the meters of wire out (MWO; from the Ship's CLAM system) over the depth at which SHRIMP was near the seabed (Fig. 3.4.4). This results in a layback (calculated from the best fit line) of between 187 m (at 4850 MWO) and 262 m (at 4700 MWO).

The correction required for the navigation is calculated from the following formulae (in degrees, with layback units as meters):

x correction = layback * sin(heading-180)
y correction = layback * cos(heading-180)

In addition to calculating the layback from the meters of wire out, we also estimated the layback by comparing the SHRIMP depth track with the Autosub bathymetry. This enabled us to make an estimation of the offset between the tracks (Fig. 3.4.5).

SHRIMP Images

A total of 742 still images were obtained from the SHRIMP deployment. These revealed a range of habitats (Fig. 3.4.6) from steep rocky cliffs to flat sedimentary areas. The photographs were generally good quality and for the majority of the deployment the altitude of the vehicle resulted in successful images. There was some vignetting of the image, an unfortunate property of the Imenco camera housing. The red scaling lasers were visible in the majority of images. A wide range of benthic organisms were imaged, including holothurians, anemones, asteroids, ascidians and sponges. A red object was imaged on the seafloor that may be a decomposing food fall, potentially a scyphomedusa such as *Periphylla periphylla*.

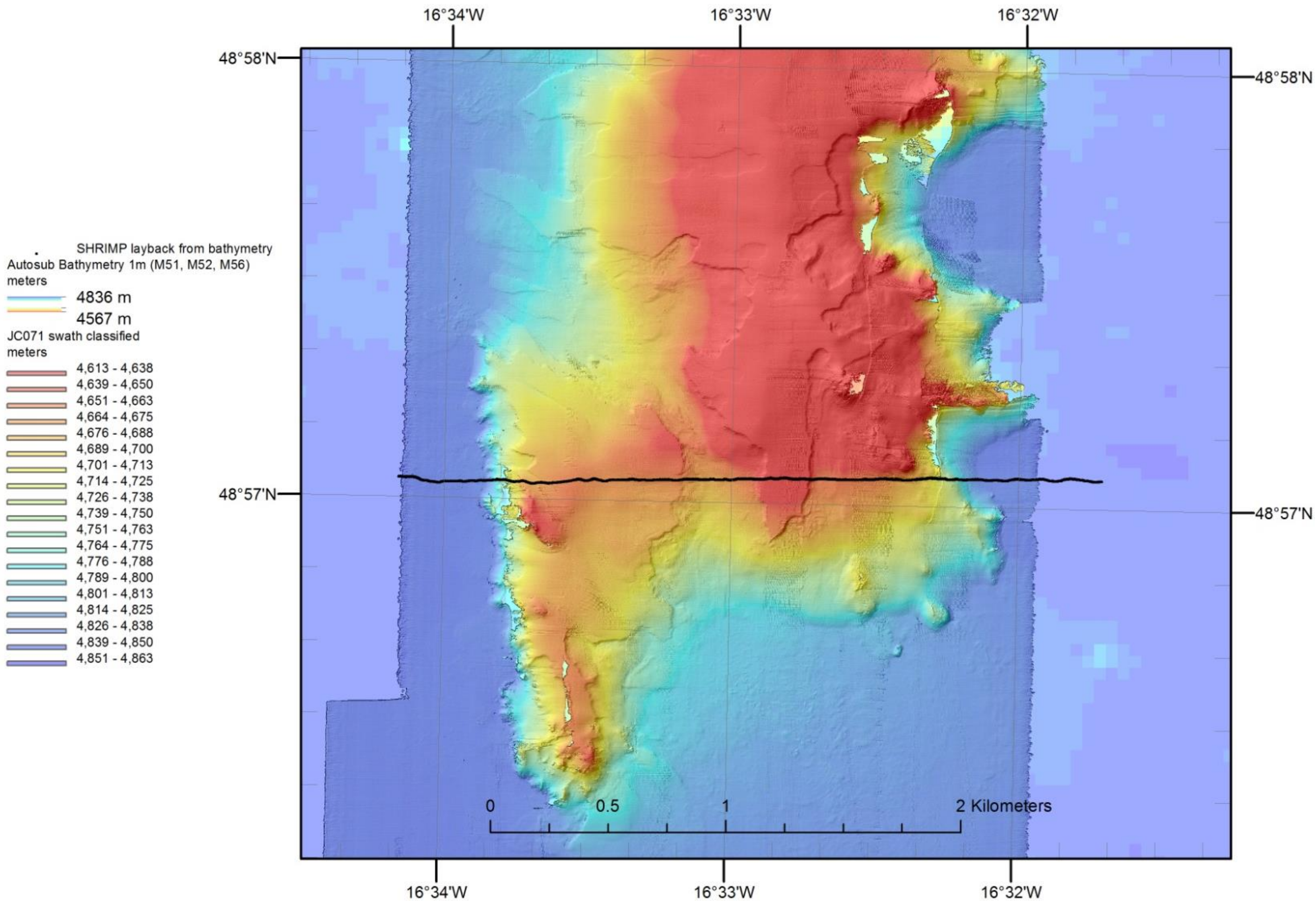

Fig. 3.4.2: Map showing the near-seabed SHRIMP track (based on bathymetrically calculated layback) over the hill feature.

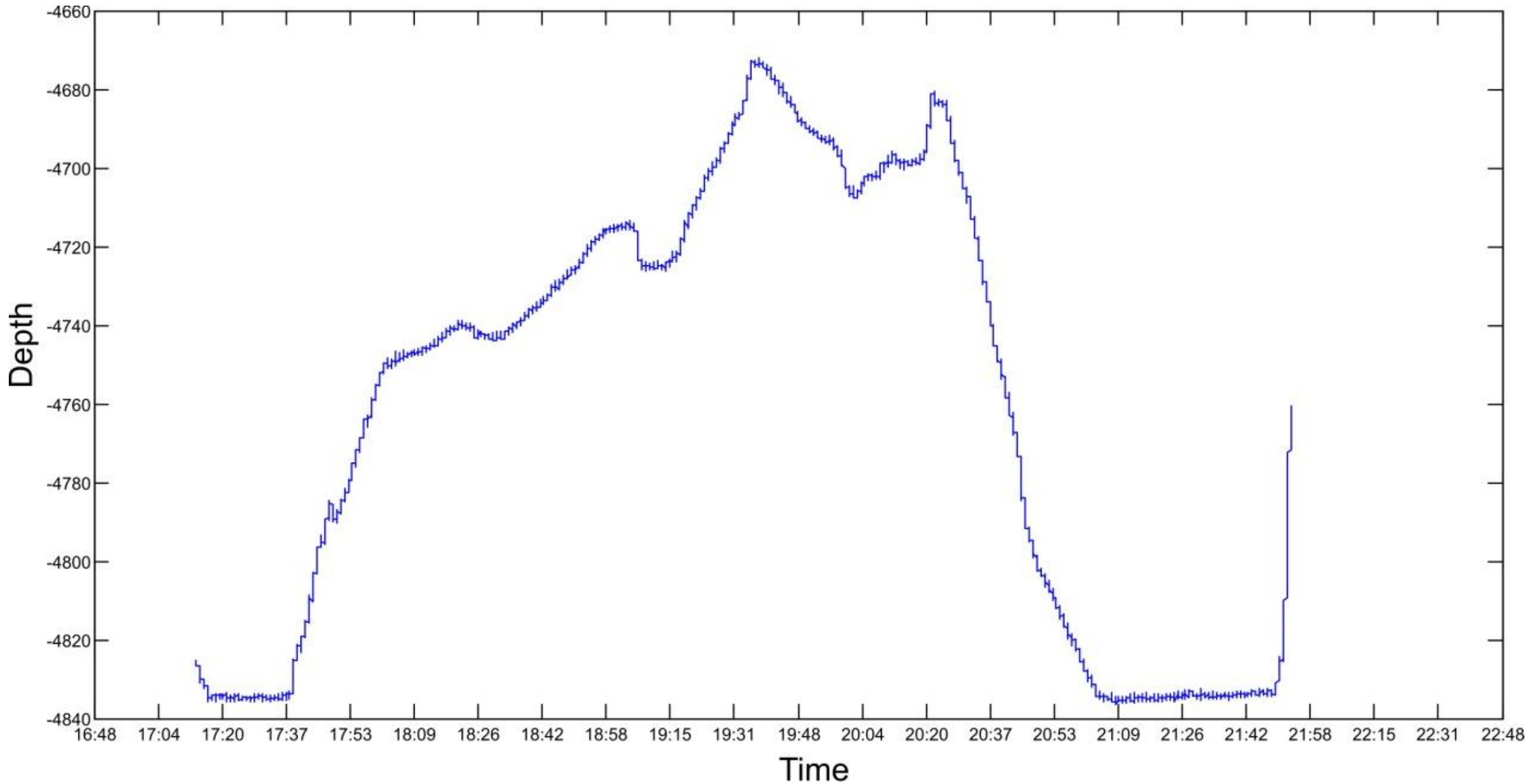

Fig. 3.4.3. Depth plot of SHRIMP track. Note depths are corrected SHRIMP depth (corrected from SHRIMP Paroscientific Digiquartz pressure sensor log using methods of Saunders and Fofonoff [Deep-Sea Res., 1976, 23, 109-111] refitted for 1980 equation of state).

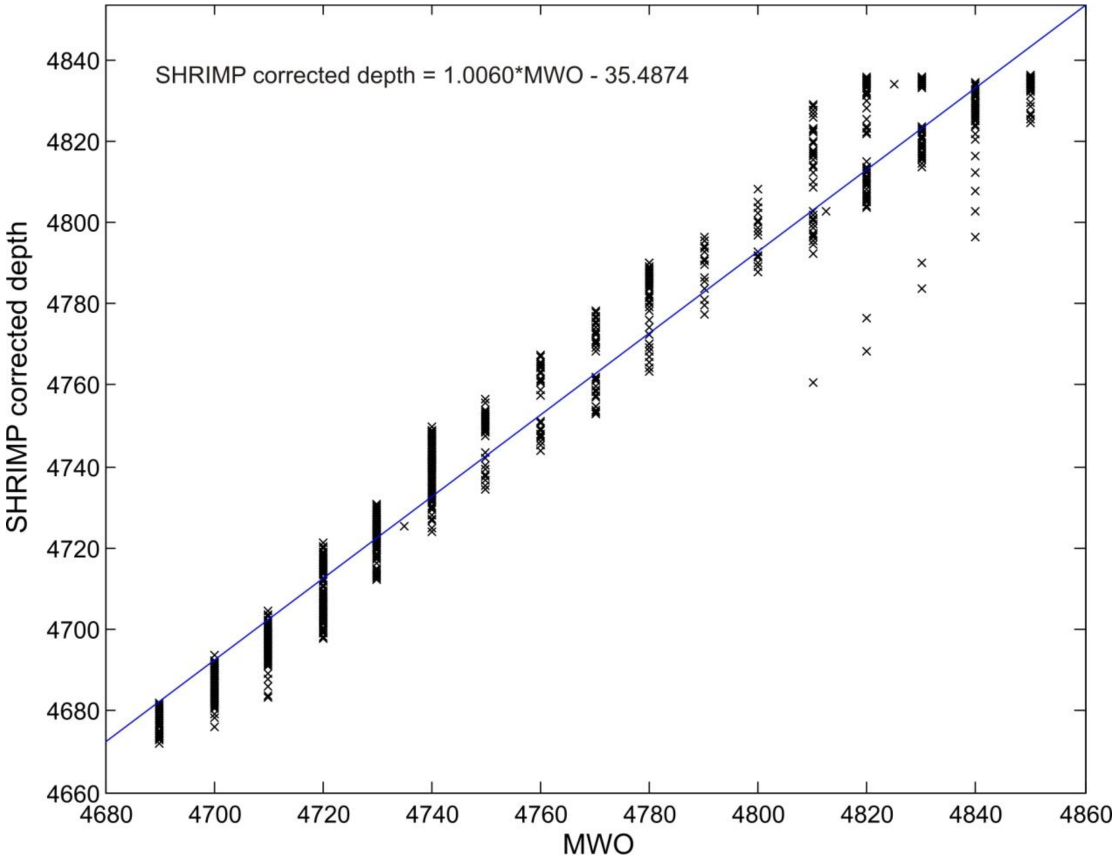

Fig. 3.4.4. Comparison of meters of wire out (from Ship CLAM system) and corrected SHRIMP depth (corrected from SHRIMP Paroscientific Digiquartz pressure sensor log using methods of Saunders and Fofonoff [Deep-Sea Res., 1976, 23, 109-111] refitted for 1980 equation of state).

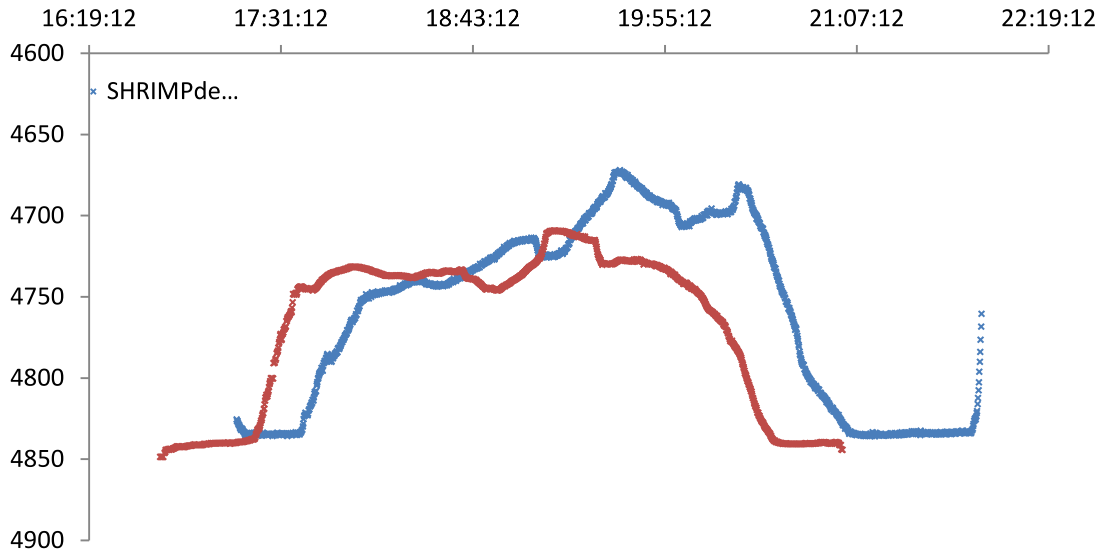

Fig. 3.4.5.1 Comparison of SHRIMP depth (from corrected vehicle pressure sensor readings) and the bathymetry data (extracted from Autosub collected swath bathymetry). No offset was applied to the vessel navigation to calculate the position of SHRIMP.

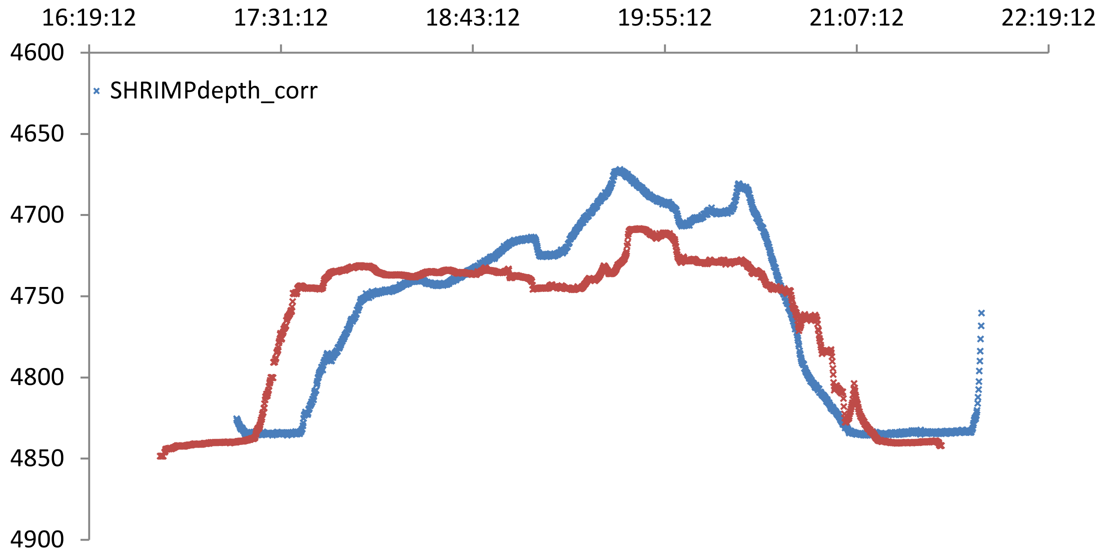

Fig. 3.4.5.2 Comparison of SHRIMP depth (from corrected vehicle pressure sensor readings) and the bathymetry data (extracted from Autosub collected swath bathymetry). An offset based on the meters of wire out and the course made good was applied to the vessel navigation to calculate the position of SHRIMP.

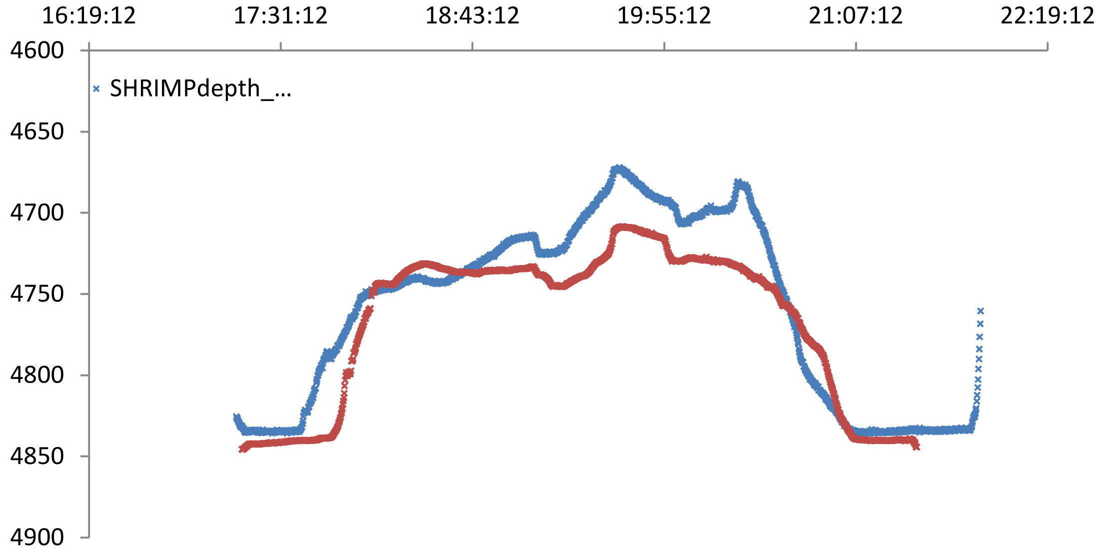

Fig. 3.4.5.3: Comparison of SHRIMP depth (from corrected vehicle pressure sensor readings) and the bathymetry data (extracted from Autosub collected swath bathymetry). A 295 m offset (west of vehicle position) was applied to the vessel navigation to calculate the position of SHRIMP.

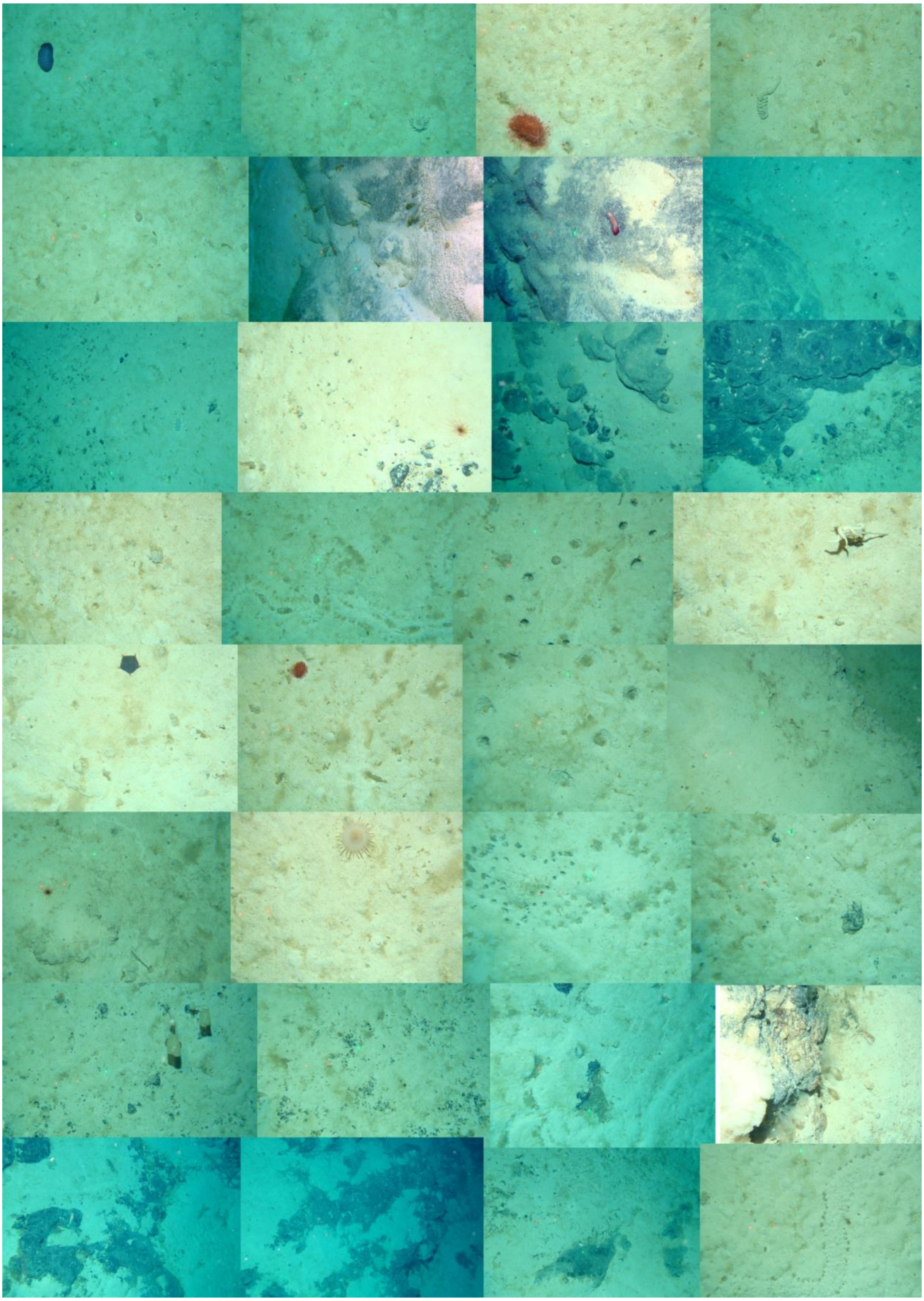

Fig. 3.4.6. Highlight photos taken along SHRIMP run. The photographs are arranged chronologically with the start at the top left and end at the bottom right.

3.5 *Autosub6000 Surveys*

3.5.1 *PAP*

3.5.1.1 *Bathymetric Surveys - Katleen Robert*

A Simrad EM2000 echosounder (111 beams) mounted on Autusub6000 (with a 0.5° roll correction) was used to collect bathymetric data, flying at ~100 m above the seabed. The raw data files were imported into CARIS HIPS and SIPS for visualization and editing. The offshore tidal computation software POLPRED (NERC) was used to predict and correct for tidal variations. A sound velocity profile based on the fourth CTD cast of the cruise was employed, but a further correction of 22 m/s had to be added. The AUV's time-stamped depths were entered as a delta draft correction.

The data were examined for navigation and attitude after which a BASE (Bathymetric Associated with Statistical Error) surface was created over a 1m grid. 2D surface subset editing was also carried out. Large offsets in navigation between missions were observed; 105 m (y-direction) and 40 m (x-direction) for mission 052 and, 250 m (y direction) and 30 m (x-direction) for mission 056. A further ~22 m offset in the z-direction was observed when compared to ship-based bathymetry obtained during the JC-71 cruise. Using a new sound velocity profile for each mission base on the AUV mounted CTD data may reduce this difference.

Eight ~10 km long swaths separated by 310 m were collected for a total coverage area of ~28.8 km^2. A raster representing the total area covered was created for use into ESRI ArcGIS (WGS 1984 UTM Zone 28N coordinate system).

Table 3.5.1. Autosub missions with multibeam echosounder data acquisition.

Mission	Date	Location	Area (km^2)
051	14 July 2012	PAP	11.5
052	16 July 2012	PAP	9.4
056	21 July 2012	PAP	11.2

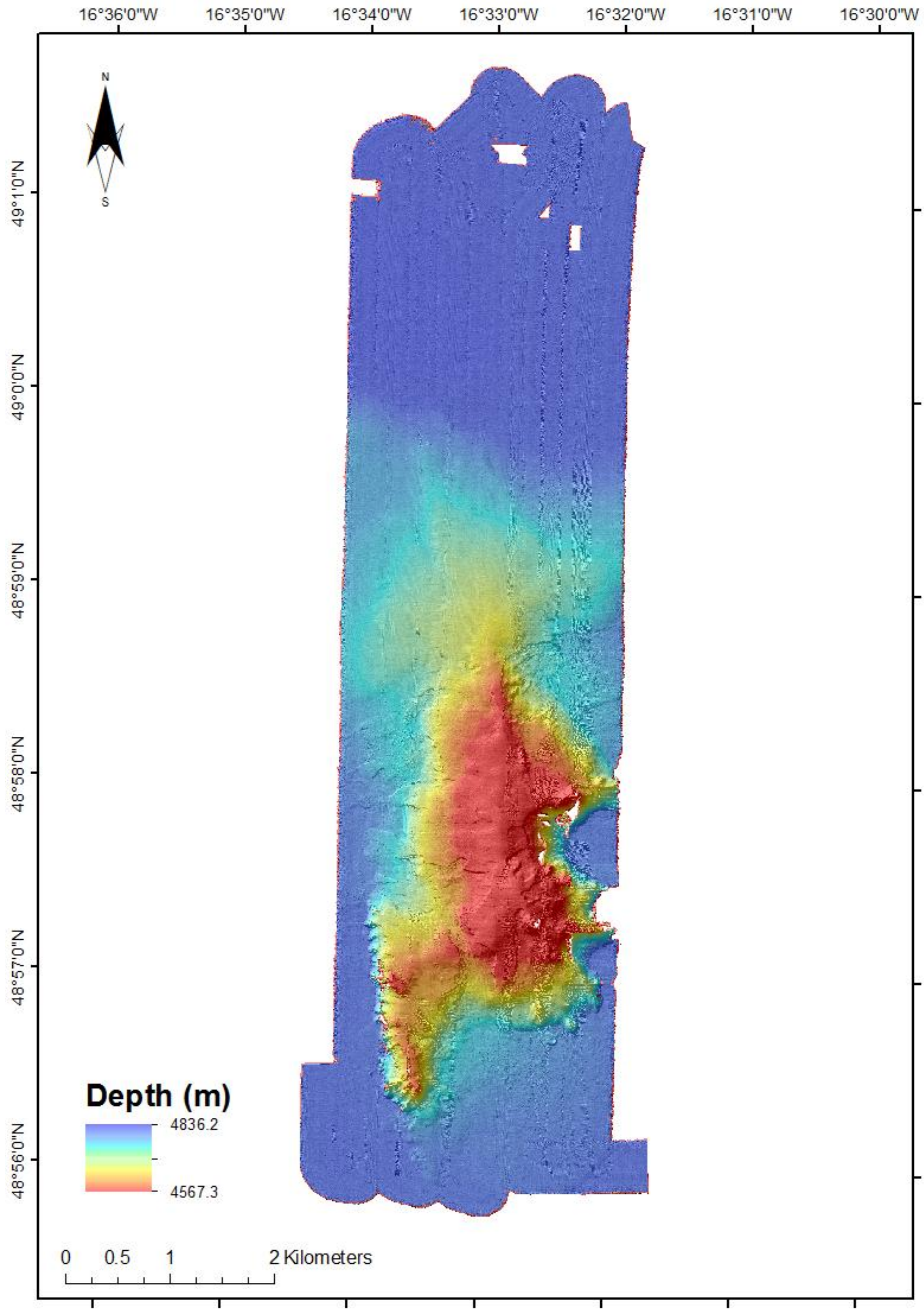

Fig. 3.5.1 Chart of Autosub6000 multibeam echosounder coverage over the AESA area.

3.5.1.2 Ecological Surveys - Rosanna Milligan, Jen Durden et al.

The effects of habitat heterogeneity and topographic relief on the distribution patterns of megafauna in the abyss are poorly known, particularly for mobile fauna such as fish which are relatively scarce and are believed to range over larger distances in search of food. The abundance and diversity of abyssal fish has been examined in both the north-east Pacific and Atlantic Oceans using trawl surveys (e.g. Merrett *et al.*, 1991, Priede *et al.* 2010), baited and unbaited camera lander systems (e.g. Smith *et al.*, 1992, 1993, Thurston *et al.*, 1995, Smith *et al.*, 1997), or towed camera systems (e.g. Lauerman *et al.*, 1996, Bailey *et al.*, 2006). However, the relative scarcity of fish at abyssal depths means that any investigations of their distribution patterns should be conducted over broad spatial scales. Autosub6000 is able to cover large distances and carry a number of instrument modules for surveying benthic or pelagic systems to depths of up to 6000 m.

The present study therefore represents the first attempt to use an AUV (Autosub6000) to investigate the distribution patterns of sessile and mobile megafauna at two sites at the Porcupine Abyssal Plain and their relation to topographical and other spatial features on the seabed (see also related efforts on cruises JC062 and JC071.

Methodology: One downward-facing and one forward-facing (oblique-view) stills camera were utilised during surveys at stations D377-34, -43, -47, -49 and -50. A summary of each deployment and the number of useable images (taken as successful images recorded at altitudes between 2-4 m above the seabed) is given in Table 1. Both cameras were programmed to capture images at intervals of approximately 0.86 seconds to provide continuous coverage of the seabed.

Table 3.5.2. Total numbers of images taken during each deployment and the numbers taken between 2 and 4 m above bottom at the seabed. The final numbers use in analyses may vary due to changes in image quality after image colour, brightness and noise corrections.

Station no.	Seabed transect length (km)	Approx. Seabed Images: Forward Camera	Approx. Seabed Images: Downward Camera	All Images: Forward Camera	All Images: Downward Camera
D377-34	2.0	0	1100	0	1400
D377-43	61.1	36600	36600	58709	58482
D377-47	63.8	0	40200	0	57119
D377-49	120.4	71000	71000	100387	99051
D377-50	54.4	36250	36250	91190	90563
TOTAL	*301.7*	*143850*	*185150*	*250286*	*306615*

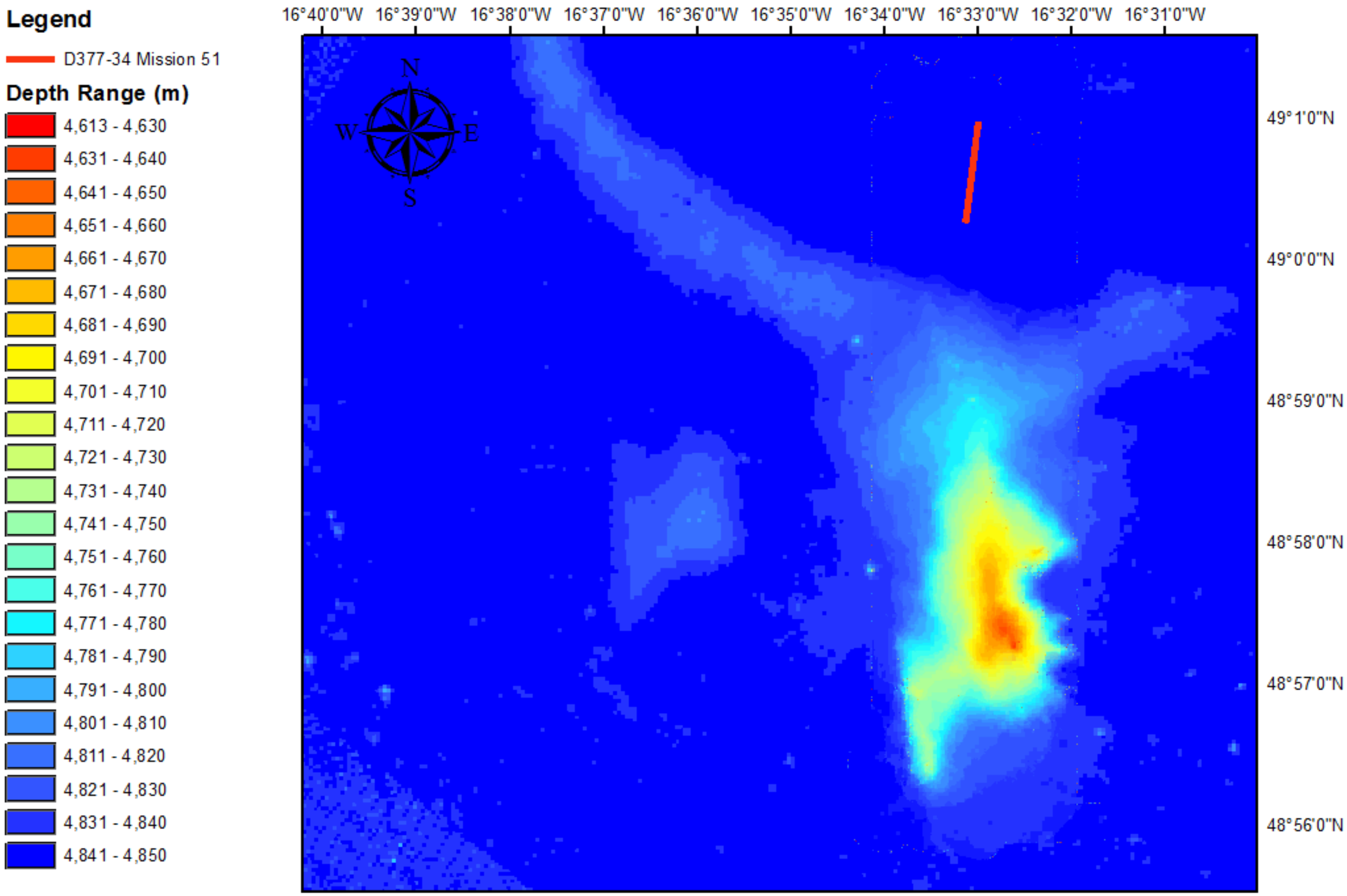

Figure 3.5.2. Bathymetric map showing the location of images taken at the seabed during D377-34 (Autosub mission 51).

This deployment was conducted primarily to gather multibeam data of the AESA area, but also contained a short seabed survey to test the camera systems. The forward camera was not functional during this test due to battery problems, but approximately 1400 images were successfully collected by the downward-facing camera over 2.03 km.

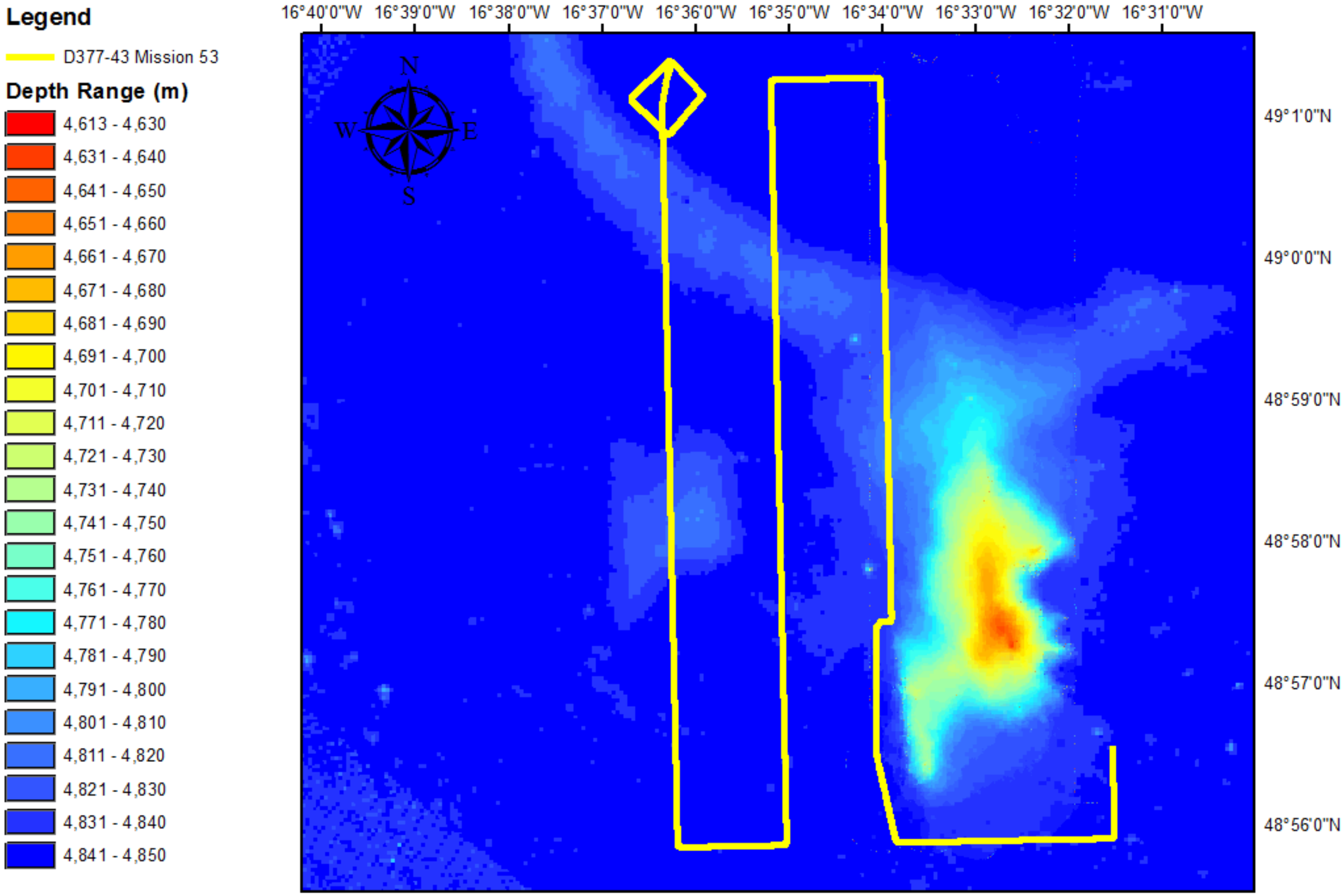

Figure 3.5.3. Bathymetric map showing the location of images taken at the seabed during D377-43 (Autosub mission 53).

Autosub conducted 61.1 km broad-scale transect to the west of the abyssal hill at the AESA area, transiting the north-south lines. The survey area is shown in figure 2, and was mostly conducted on flat areas of seabed, with both cameras working well throughout the survey and recovering approximately 73,000 images from the seabed. The forward-facing camera used in this deployment captured images in black and white.

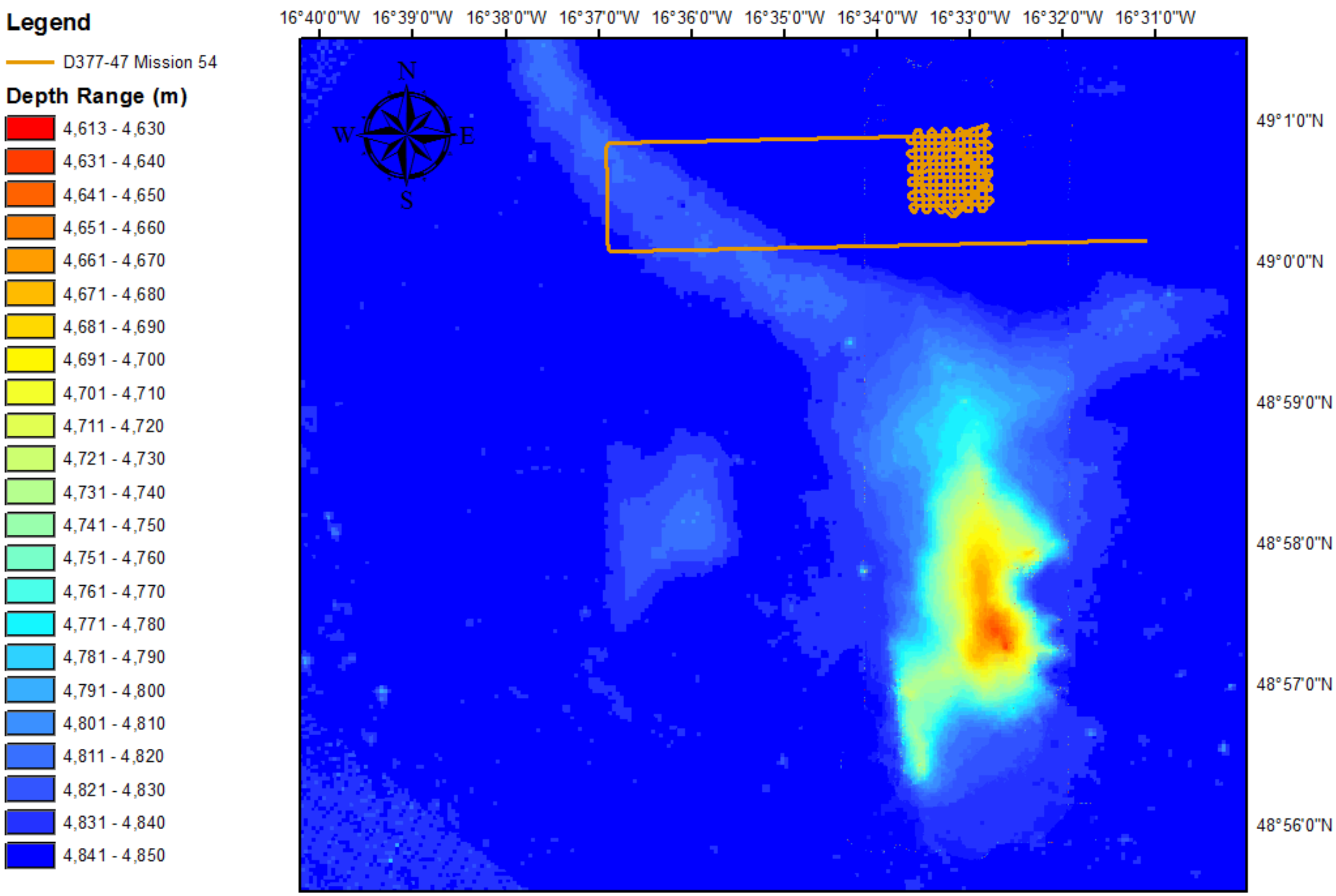

Figure 3.5.4. Bathymetric map showing the location of images taken at the seabed during D377-47 (Autosub mission 54).

This deployment included a fine-scale survey (1 km^2 box followed by an east-west section of the broad-scale survey on flat ground to the north of the hill at the AESA area. The survey location is shown in figure 3, and covered 63.8 km of seabed. Unfortunately the forward-facing camera failed on deck immediately prior to launch and so images were only recovered from the downward-facing camera.

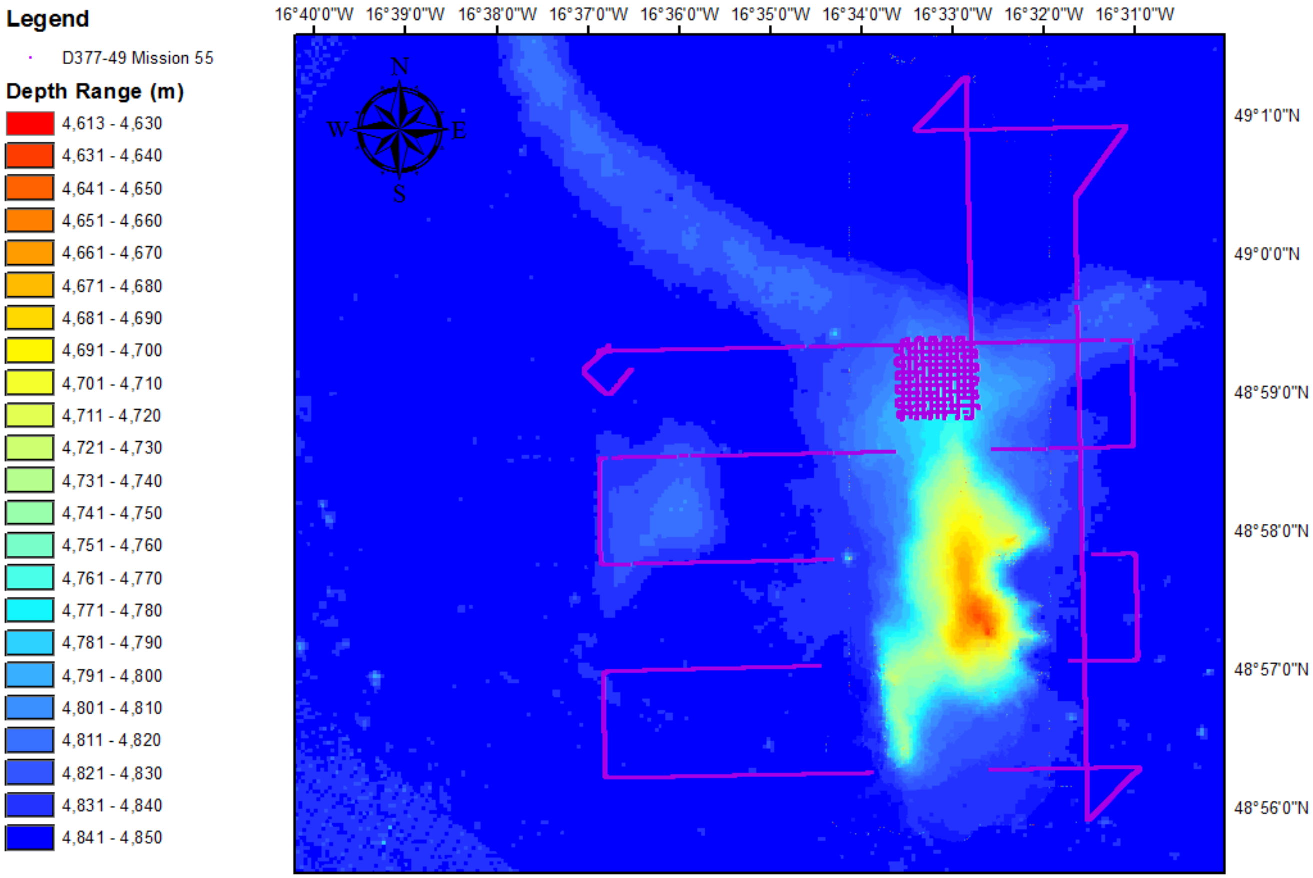

Figure 3.5.5. Bathymetric map showing the location of images taken at the seabed during D377-49 (Autosub mission 55).

This deployment covered the remained of the broad-scale survey (covering east-west transects in the southern part and north-south transects in the east) over flat ground, and ended with a fine-scale survey over higher ground to the north of the abyssal hill (Fig. 4). Due to concerns over the reliability of the collision-avoidance system on the AUV it was decided to avoid surveying the high ground of the abyssal hill, resulting in breaks in the survey lines as Autosub crossed the hill at higher altitude. The survey was successful, covering a total distance of 120.4 km across the seabed and recovering approximately 140,000 seabed images from both cameras. The black and white forward-facing camera was replaced by a colour model for this and all subsequent deployments. The higher ground was partially surveyed by SHRIMP and was intended to be surveyed during D377-54 (Autosub mission 57).

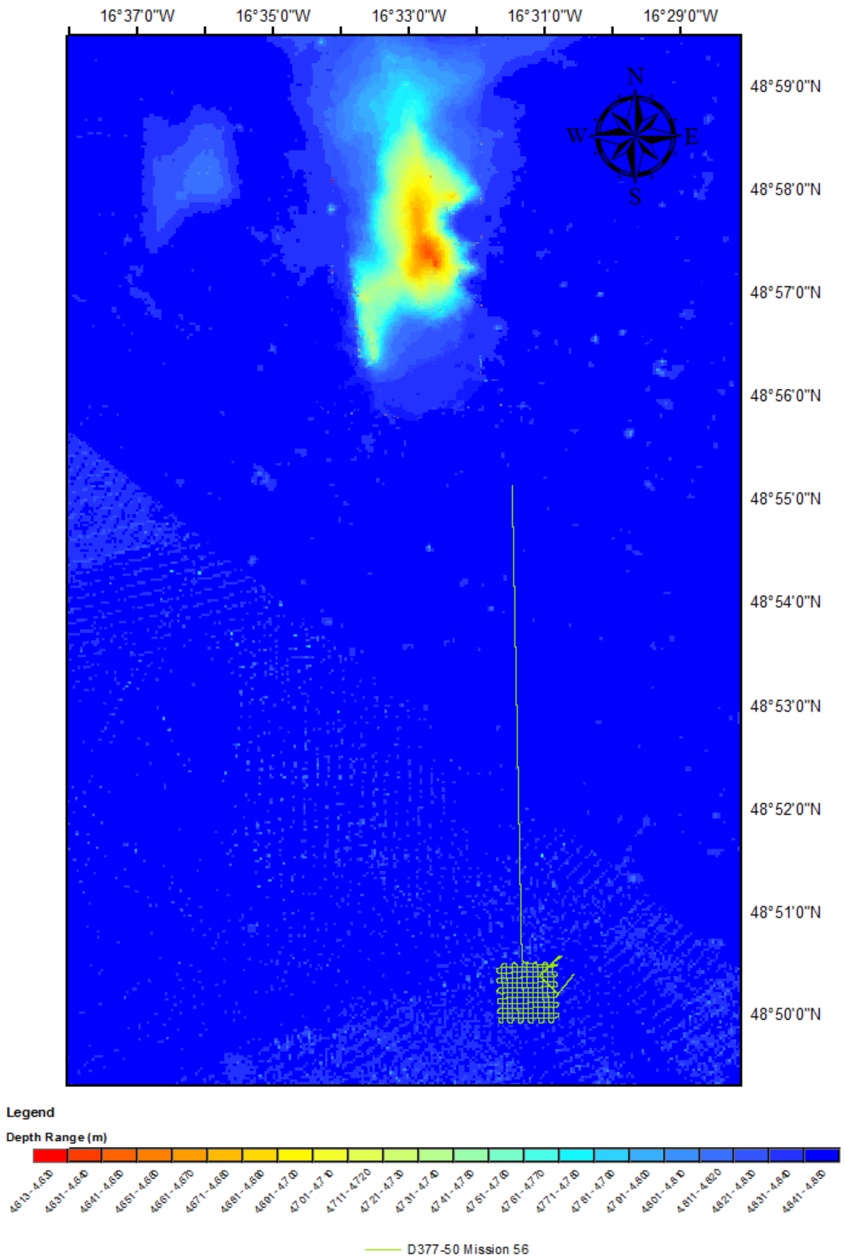

Figure 3.5.6. Bathymetric map showing the location of images taken at the seabed during D377-50 (Autosub mission 56).

This deployment began with a fine-scale survey at the PAP site, followed by a transect to the south-eastern corner of the AESA area (Fig. 5) at which point a multibeam survey was conducted for the remainder of the deployment. Due to Autosub missing one of the programmed waypoints at the end of the photographic transect, the photographic survey lines between AESA and PAP do not connect. Both cameras functioned well however, recovering approximately 72,250 images of the seabed.

D377-54 (Autosub mission 57)

This survey was intended to collect images from the elevated ground over the abyssal hill to cover the areas excluded from the survey at Station D377-49. Unfortunately, a system malfunction in Autosub meant that no seabed images were collected.

Preliminary Results

Fish - A preliminary examination of the images from the forward camera showed that Autosub was able to successfully record images of a number of species of fish, with the fauna apparently dominated by members of the Macrouridae, though specimens of the deep-sea eel *Histiobranchus bathybius* and the lizardfish *Bathysaurus* sp. were also recorded. A representative selection of images collected at station D377-49 is shown in Fig. 3.5.7. Full analysis of the mobile fauna observed during this cruise will be conducted by Rosanna Milligan on return to the University of Glasgow.

Invertebrates - A full examination of the downward facing camera images has not been completed, but photos from stations 34 and 43 are dominated by holothurians (particularly *Psychropotes longicauda* and *Amperima* or other small transparent holothurians) and actinarians or cerianthids. Other holothurians identified include *Oneirophanta mutabilis*, *Deima* sp., *Pseudostichopus villosus*, *Pseudostichopus aemulatus*, *Enypniastes eximia*, *Benthodytes* sp., *Benthothuria* sp., *Paroriza* sp and *Peniagone* sp. Other invertebrates identified include ophiuroids, *Munidopsis* sp., at least six dumbo octopus, tunicates, sponges, *Umbellula* sp., echiura, an isopod, scale worms, xenophyophores, gorgonians, crinoids, and pycnogonids. Representative images from the downward-facing camera are shown in Fig. 3.5.8.

Other observations - The sediment was largely muddy and appeared soft in the stations reviewed, with some areas of larger particles such as stones and clinker. Lebenspurren identified included asteroid and ophiuroid feeding impressions, holothurian tracks, traces attributable to gastropods, bivalves or irregular urchins, spoke burrows, enteropneust nests, mounds, holes, and both coiled and curved casts. Phytodetritus was found covering much of the seafloor in clumps, much more than was seen in the photos of the area from JC062. Areas of red detritus were also identified on the seafloor.

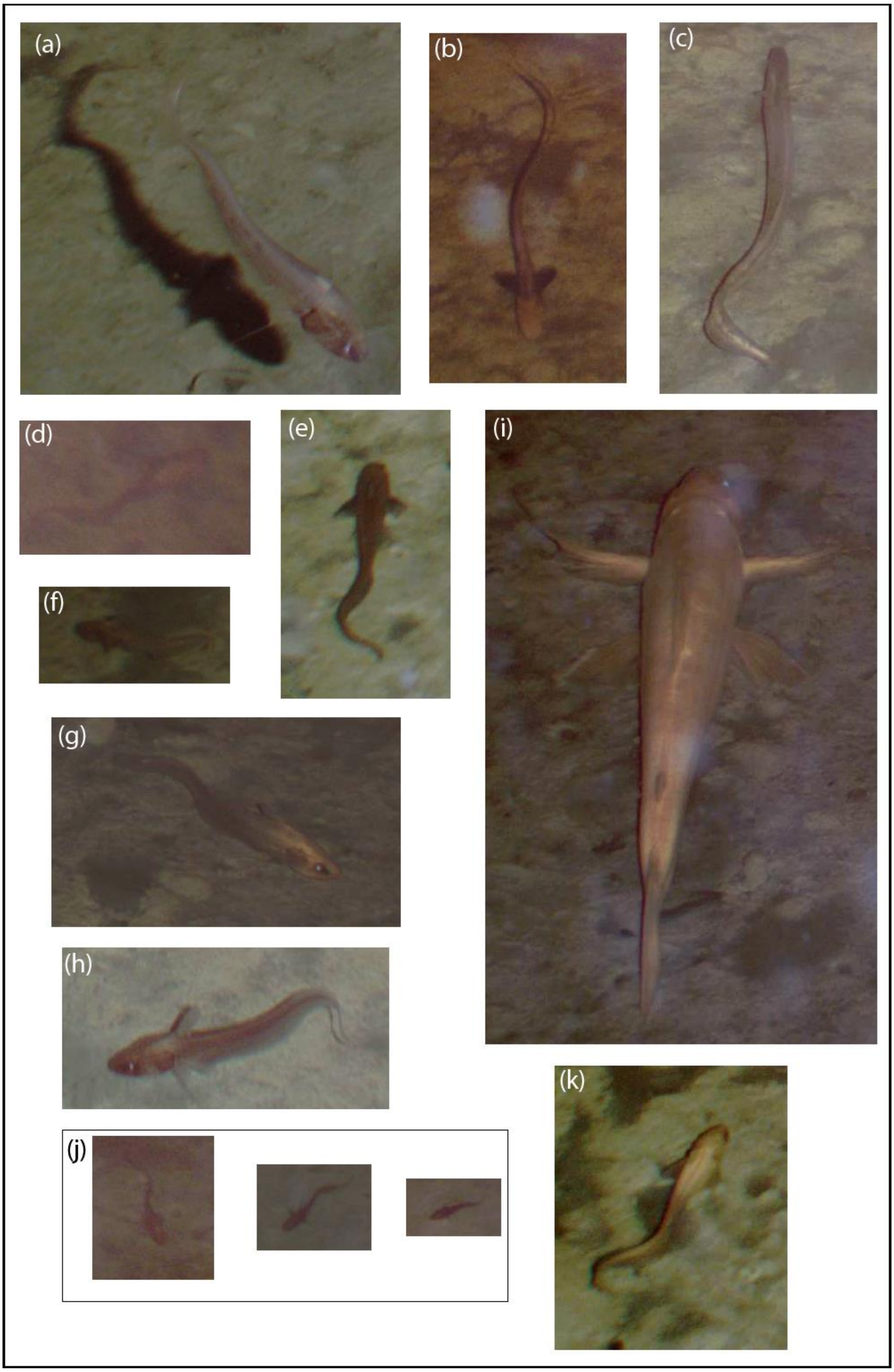

Fig. 3.5.7. A representative selection of abyssal fish seen in a subsample of seabed images taken from station D377-49. All specimens appear to be macrourids with the exceptions of: (c) Histiobranchus bathybius and (i) Bathysaurus sp. A colour cast is present on all images, and colouration should not be considered accurate at present.

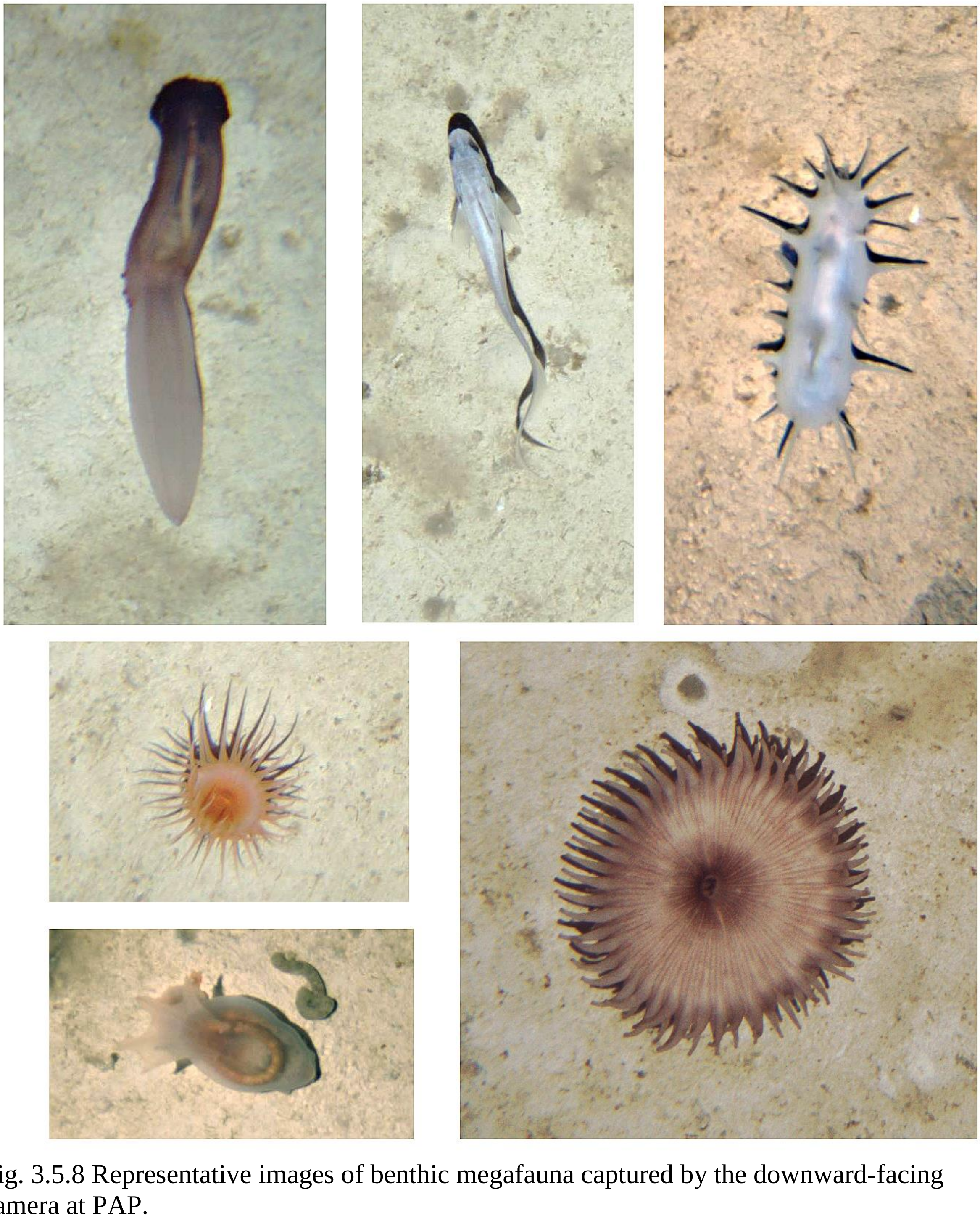

Fig. 3.5.8 Representative images of benthic megafauna captured by the downward-facing camera at PAP.

Human Impacts

The AUV photographs from both cameras showed a number of man-made items littering the seafloor (Fig. 3.5.9), which have most likely been discarded by shipping. Items included clinker, glass bottles, drinks cans, pieces of scrap metal and wood, scraps of plastic and a number of bags. Several of the items seen appeared to have been colonised by invertebrates (particularly Actinaria).

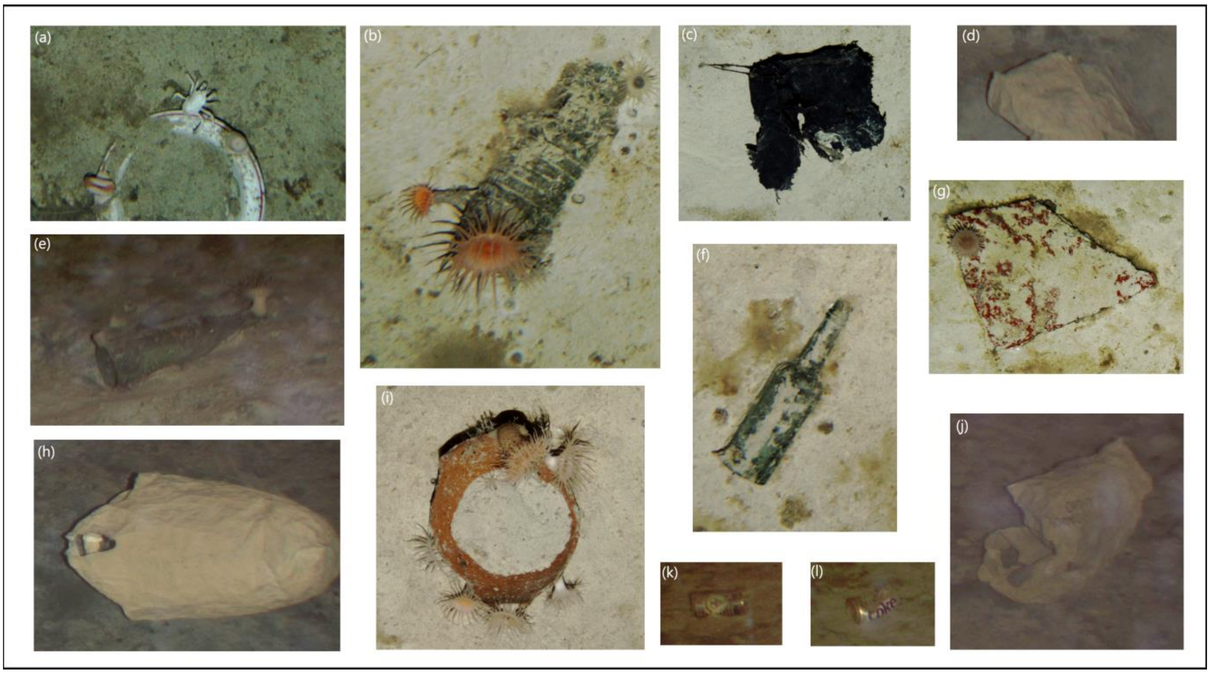

Fig. 3.5.9. Items of litter encountered during the AUV surveys: (a) dinner plate with Actinaria and Munidopsis sp.; (b) plastic bottle with Actinaria; (c) plastic bag; (d), (h) & (j) sacks (*possibly paper*); (e) & (f) glass bottles; (g) & (i) indeterminate items (possibly metal); (k) & (l) drinks cans.

3.5.2 *Haig Fras Survey*

Autosub6000 operations in the Greater Haig Fras area were undertaken as part of the Defra (Department for Environment, Food and Rural Affairs) funded project "Investigating the feasibility of utilizing AUV and Glider technology for mapping and monitoring of the UK MPA network (MB0118)", specifically Case Study 2: Shallow-water AUV mapping off SW UK. The aim of the survey was to undertake high-resolution mapping and colour photography over a recommended Marine Conservation Zone (rMCZ), in order to highlight the capability of AUV technology for high-resolution shallow-water mapping and benthic species identification.

Following discussions with Defra, JNCC (Joint Nature Conservation Committee) and CEFAS (Centre for Environment, Fisheries & Aquaculture Science), the Greater Haig Fras area (Fig. 3.5.10) was selected for the Autosub6000 Case Study 2 mission. Haig Fras itself is an isolated, bedrock outcrop some 90 km north west of the Isles of Scilly. It is thought to be the only substantial area of rocky reef in the Celtic Sea beyond the coastal margin. The rock outcrop is the focus of both a Special Area of Conservation and a recommended Marine Conservation Zone. The specific location of the Autosub6000 mission was chosen to correspond with an area of ship-based seabed survey carried out from the RV Cefas Endeavour (Fig. 3.5.11) just prior to the arrival of RRS *Discovery* cruise 377/8.

The case study was carried out as a single Autosub6000 deployment (Mission 58; 25-26 July 2012; NOC station number D377-062). The mission comprised of four separate dives:
Dive 1 – Vehicle sensor test (including camera trial)
Dive 2 – Swath bathymetry survey (including camera trial), survey altitude 50m
Dive 3 – Photographic survey, survey altitude 3m
Dive 4 – Sidescan sonar survey, survey altitude 15m

This milti-dive mission operation allowed us to (a) check the correct operation of the vehicle, particularly that useful photographic images were being obtained, and (b) initiate each phase of the survey (dives 2-4) with a new GPS fix at the surface. Dive tracks and profiles are shown in the Figs. 3.5.11 and 3.5.12.

For mission 58 the key sensors were:
- EM2000 multibeam system
- EdgeTech 2200-FS dual frequency sidescan sonar (120/410kHz)
- Point Grey Research Grasshopper 2 digital camera with 10J flashgun
- Seabird CTDs (Conductivity, Temperature, Depth instrument)
- Sea Point LSS (light scattering sensor)
- RDI Teledyne 300kHz ADCP

Details of photographic set-up:

- Frame interval: 850mS
- Camera down-angle: 90°
- Lens type: Navitar
- Lens focal length: 12mm
- Lens f number: c. 2
- Focus in air: 2.5m
- Flash energy: 10J
- Shutter speed: 1mS
- Camera model: Point Grey Research, Grasshopper2, GS2-GE-50S5C
- Imaging sensor: Sony ICX625AQ (2/3" 2448x2048 CCD)
- Resolution: 2448x2048 pixels
- Image recording format: raw 8-bit, Bayer tile format: GBRG

Table 3.5.3. Mission details for both

Mission	Date	Location	Area (km2)
058	25 July 2012	Haig Fras	3.9

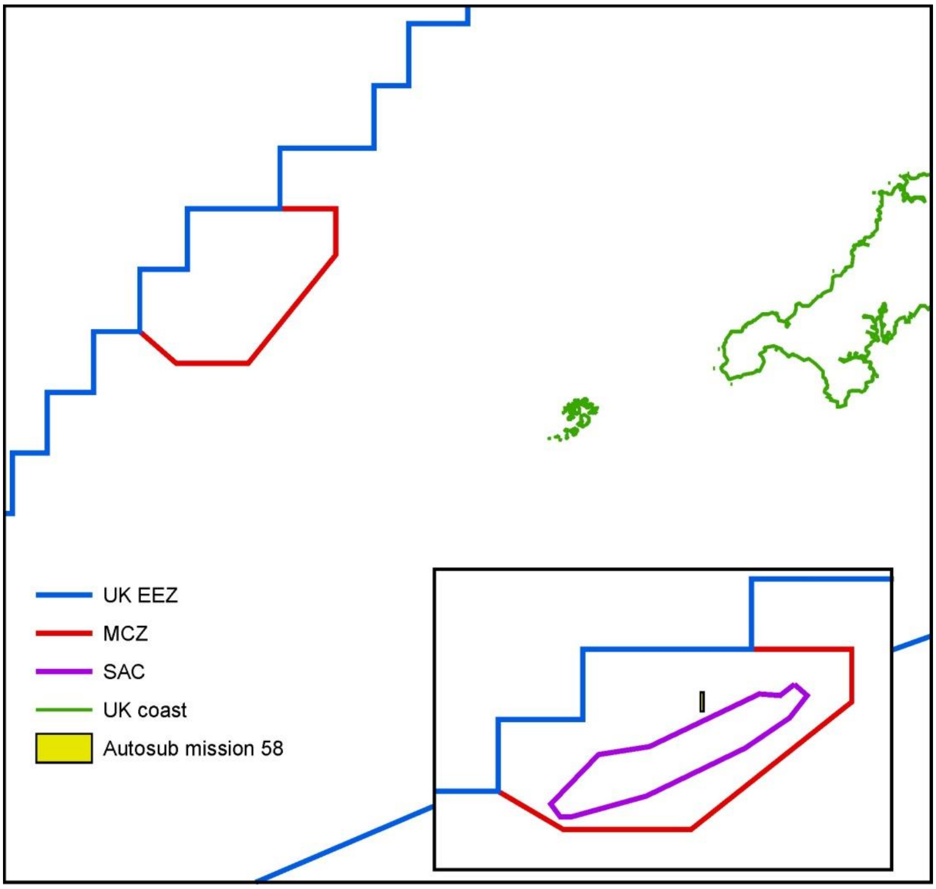

Fig. 3.5.10. General location map for Autosub6000 mission 58 within the Greater Haig Fras recommended Marine Conservation Zone (MCZ) adjacent to the Haig Fras Special Area of Conservation (SAC).

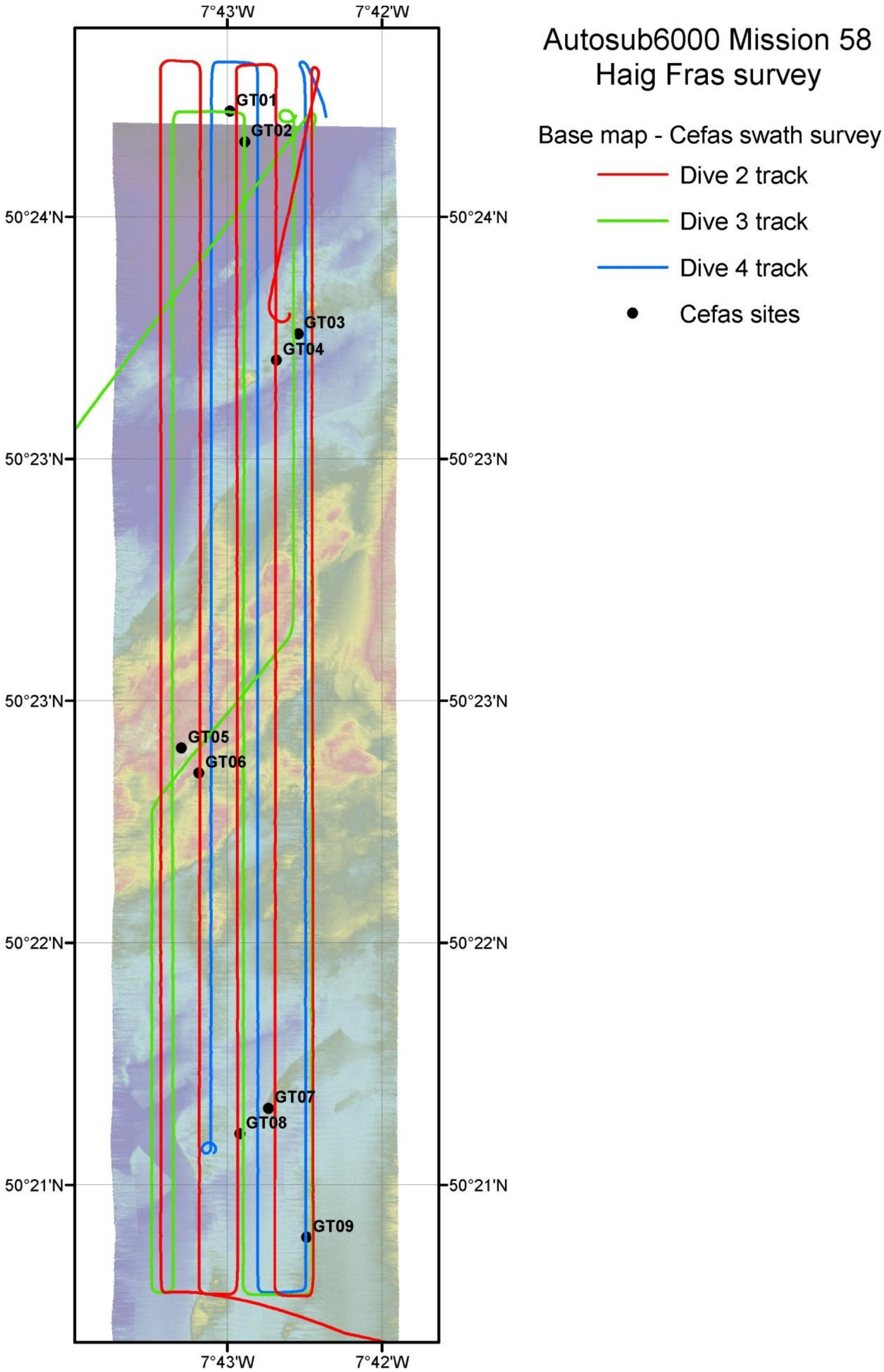

Fig. 3.5.11. Track lines for Autosub6000 dives 2-4 of mission 58 overlain on multibeam swath bathymetry map supplied from preceding cruise of RV Cefas Endeavour (also shown are locations of Cefas ground truth sites 1-9).

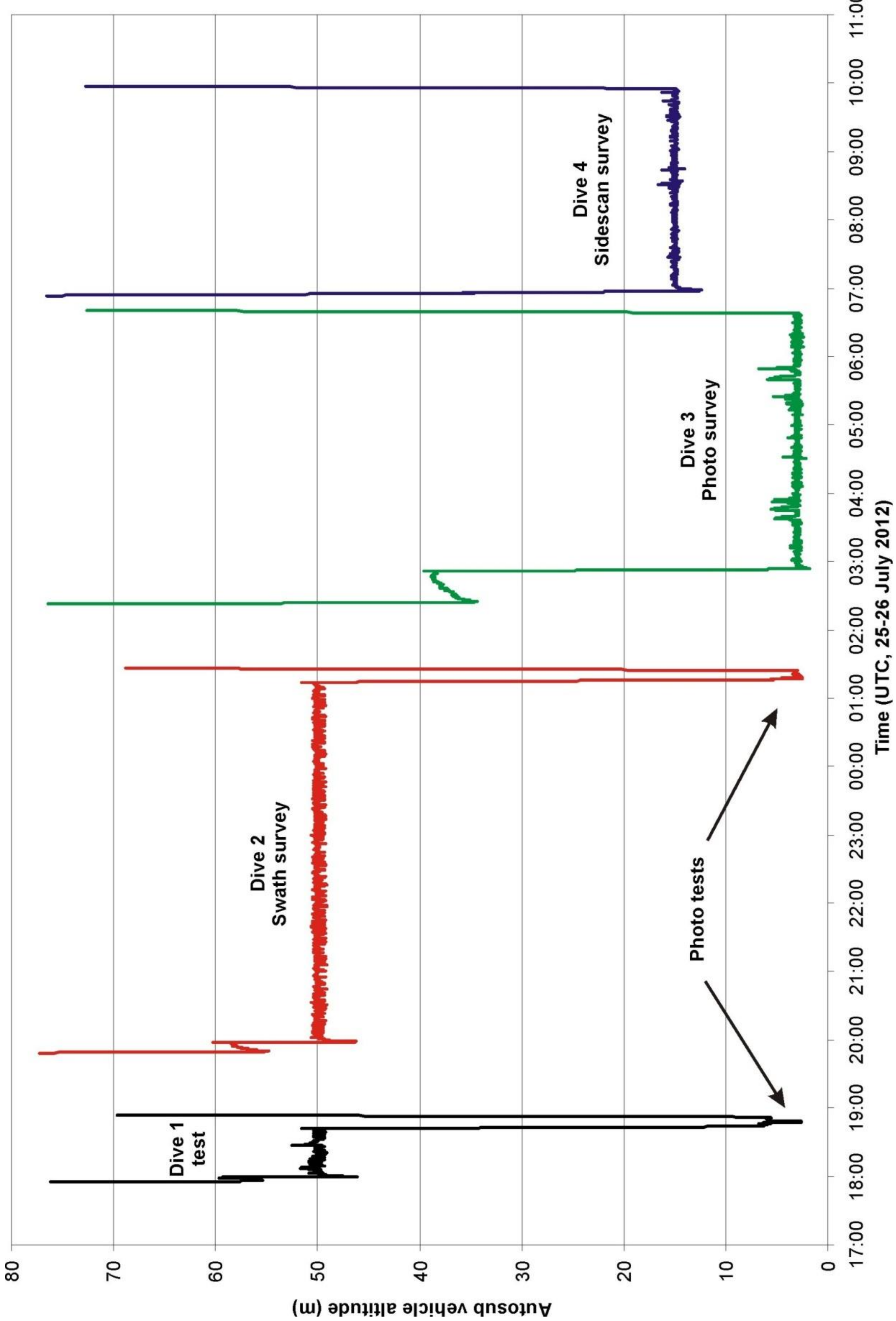

Fig. 3.5.12. Autosub6000 mission 58, dives 1-4, showing dive profiles as vehicle altitude against time.

3.5.2.1. *Bathymetric survey*

For this survey, Autosub6000 was flying at ~50 m above the seabed. The same approach was taken for analysis of the multibeam data; except for the sound velocity profile which was generated based on the AUV mounted CTD data. Mission 58 consisted of five ~4.7 km transect lines separated by 150m resulting in a total area of ~3.9 km^2.

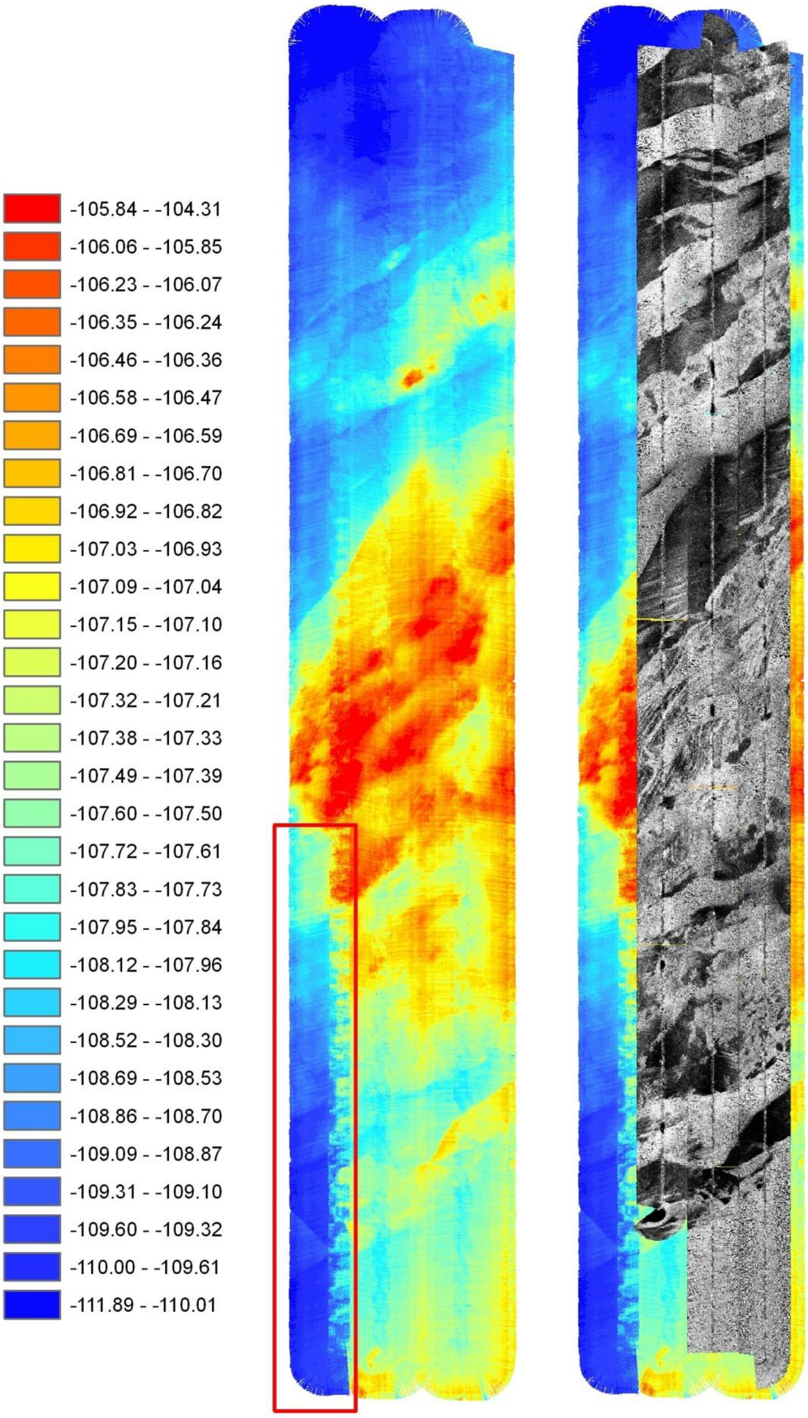

Fig. 3.5.13. Autosub6000 mission 58, multibeam swath bathymetry (dive 2) and sidescan sonar backscatter (dive4). (High backscatter – light; low backscatter dark). (Red box indicates area of biased data from erroneous vehicle depth record).

In general terms the sidescan data has alternating bands of higher and lower backscatter having a broadly similar SW to NE trend. In simple terms these may be interpreted as changes from coarser mixed sediments (high backscatter) to finer more homogeneous sediments (low backscatter). Many other finer-scale details are apparent on close inspection of this data. Of particular interest are areas of sinusoidal striations on the central high region that may be interpreted as outcropping rock strata.

3.5.2.2. *Ecological survey*

CTD and LSS

Although undertaken as a seabed survey, mission 58 also generated useful data on the environment of the over-lying water column. Fig. 3.5.14 illustrates the water column profiles of CTD and LSS instrument data. A strong thermocline is evident between 30 and 50 m water depth, with ~10 m variance in its location that may be attributed to both temporal and spatial variations. Salinity profiles exhibit similar variation. Turbidity, as determined from the light scattering sensor, shows a marked increase below the thermocline, generally increasing with proximity to the seafloor.

Photographic survey

The AESA camera systems were run continuously during Autosub6000 mission 58. Only those images recorded from the downward facing camera during dive 3 have been examined to date. In total some 16,000 images were recorded during dive 3, around 15,000 of those during the near-seabed phase of the dive. For initial study, the raw format images recorded were batch converted to jpeg images at 80% image quality and with automatic colour correction using IrfanView (V 4.33) software. The images are somewhat degraded by particle backscatter in the near-bottom water; however, they are of good quality for seabed characterisation.

Selected examples of the benthic invertebrates and demersal fish encountered during Autosub6000 mission 58 dive 3 are shown in Fig. 3.5.15. The invertebrate megafauna included several species of sponge (images 1-4); anthozoans (anemones: Actinaria; Zoanthidea; Ceriantharia; images 5-10); ‘Ross coral’ the bryozoan Pentapora fascialis (images 11-12); the ‘coral worm’ Salmacina dysteri (images 13-14); several species of starfish and brittle stars (images 15-20); octopus and cuttlefish (images 21-22); stone crabs and squat lobsters (images 23-24). The demersal fish fauna included smooth hound, bull huss, skate, cuckoo ray, rockling and megrim (images 25-30).

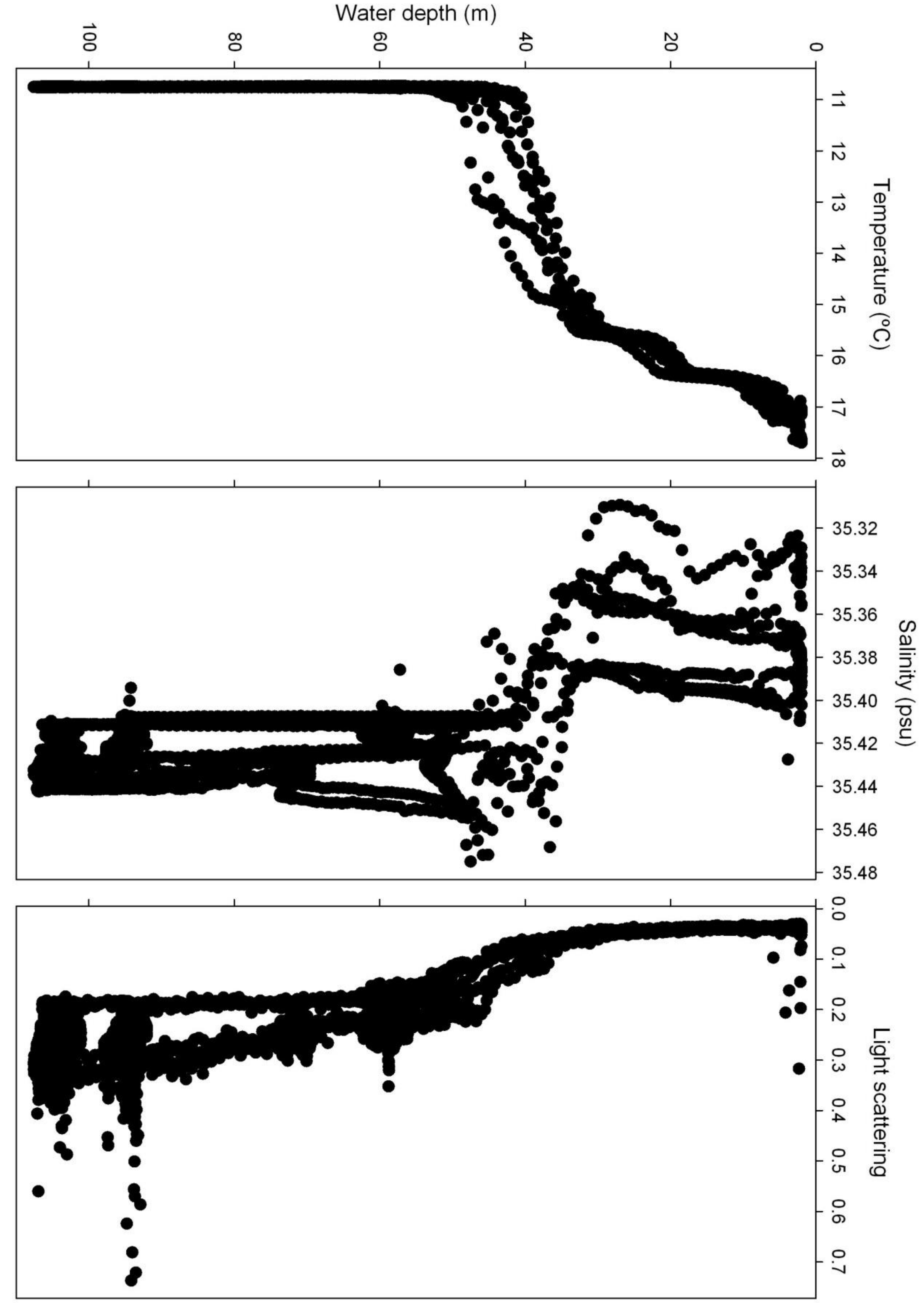

Fig. 3.5.14. Autosub6000 mission 58, dives 1-4, water column profiles of CTD and LSS instrument data.

Fig. 3.5.15. Selected examples of the benthic invertebrates and demersal fish encountered during Autosub6000 mission 58 dive 3. (images 1-30 reading left to right, top to bottom).

4.0 Station list. Part 1 of 2 (times in bold indicate they occur on the following day).

Event No.	Date	Station	Cast/ dive	Lat. (deg)	Lat. (decimal minites)	Long. (deg)	Long. (decimal minites)	Depth (m corr)	Time IN Water (GMT)	Time at BOTTOM/all out (GMT)	Time OUT Water (GMT)	Activity	Comments
D377-001	07/07/2012	Goban Spur	1	49	35.520	11	50.840	1011	04:15	05:05	05:31	CTD	for experiments
D377-002	07/07/2012	Goban Spur	2	49	35.510	11	50.730	992	09:22	10:56	11:25	CTD	all fired, for experiments
D377-003	07/07/2012	Goban Spur		49	35.630	11	50.900	997	17:54	18:34	19:10	Megacore	6 tubes, for experiments
D377-004	07/07/2012	Goban Spur		49	35.796	11	51.429	1005	19:46	20:30	20:34	Megacore	6 tubes, for experiments
D377-005	07/07/2012	Goban Spur		49	35.530	11	50.860	995	21:45	22:25	23:06	Megacore	6 tubes, for experiments
D377-006	07/07/2012	Goban Spur		49	35.610	11	50.790	995	23:40	***00:21***	***01:00***	Megacore	8 tubes, for experiments
D377-007	08/07/2012	Goban Spur		49	35.620	11	50.800	995	01:15	01:51	02:23	Megacore	6 tubes, for experiments
D377-008	08/07/2012	Goban Spur		49	35.630	11	50.800	993	02:45	03:21	03:25	Megacore	6 tubes, for experiments
D377-009	08/07/2012	Goban Spur		49	35.630	11	50.830	995	04:39	05:11	05:15	Megacore	6 tubes, for experiments
D377-010	09/07/2012	E1		49	1.135	16	33.190	4847	05:13	07:27		Megacore	8+2
D377-011	09/07/2012	D1		48	59.548	16	31.626	4820	10:37	12:47	15:00	Megacore	8+2
D377-012	09/07/2012	AESA area	M49	49	1.410	16	34.260		17:23		18:14	Autosub6000	battery leak, aborted
D377-013	09/07/2012	D2		48	56.349	16	32.730	4829	20:36	23:06	***01:39***	Megacore	7+3
D377-014	10/07/2012	C1		48	58.920	16	32.810	4775	02:11	04:21	06:28	Megacore	7+3
D377-015	10/07/2012	C2		48	58.796	16	32.787	4766	07:02	09:14	11:24	Megacore	7+3
D377-016	10/07/2012	AESA area	3	48	56.386	16	33.056	4808	12:24	14:25	17:00	CTD	prokaryote distribution
D377-017	10/07/2012	E3		49	1.186	16	36.378	4847	18:50	21:25	23:50	Megacore	7+3
D377-018	11/07/2012	E2		49	0.821	16	35.176	4848	00:20	02:40	04:50	Megacore	7+3
D377-019	11/07/2012	D3		48	56.298	16	36.189	4845	05:44	07:55	08:00	Megacore	7+3
D377-020	11/07/2012	D4		48	56.214	16	36.749	4842	10:37	12:49	15:01	Megacore	7+3
D377-021	11/07/2012	D5		48	57.015	16	35.102	4839	15:37	17:56	20:00	Megacore	7+3
D377-022	11/07/2012	C3		48	57.120	16	32.065	4844	20:51	23:22	***01:35***	Megacore	7+3
D377-023	12/07/2012	C4		48	58.590	16	32.864	4728	02:21	04:55	04:58	Megacore	7+3
D377-024	12/07/2012	B1		48	57.808	16	33.182	4677	07:37	09:46	09:50	Megacore	7+3
D377-025	12/07/2012	B2		48	57.061	16	33.007	4679	13:47	16:26	18:50	Megacore	7+3
D377-026	12/07/2012	AESA area	M50	49	1.496	16	34.747	4811	20:15		***01:41***	Autosub6000	voltage drop, aborted
D377-027	13/07/2012	B3		48	57.992	16	32.723	4680	03:13	05:20	07:21	Megacore	7+3
D377-028	13/07/2012	B4		48	57.035	16	32.399	4705	08:01	10:04		Megacore	7+3, failure
D377-029	13/07/2012	A1		48	57.358	16	32.726	4630	13:06	15:24	17:50	Megacore	7+3
D377-030	13/07/2012	A2		48	57.785	16	32.856	4678	18:20	20:47	23:20	Megacore	7+3
D377-031	14/07/2012	A3		48	57.240	16	32.722	4636	00:01	02:15	04:22	Megacore	7+3
D377-032	14/07/2012	A4		48	57.304	16	32.778	4634	04:57	07:01		Megacore	7+3

4.0 Station list. Part 2 of 2 (times in bold indicate they occur on the following day, underlined is two days later).

Event No.	Date	Station	Cast/ dive	Lat. (deg)	Lat. (decimal minites)	Long. (deg)	Long. (decimal minites)	Depth (m corr)	Time IN Water (GMT)	Time at BOTTOM/ all out (GMT)	Time OUT Water (GMT)	Activity	Comments
D377-033	14/07/2012	AESA area	4	49	1.385	16	34.229	4846	10:27	12:14	14:46	CTD	prokaryote dist., experiments
D377-034	14/07/2012	AESA area	M51						18:49		09:05	Autosub6000	multibeam mission
D377-035	15/07/2012	BB1		48	57.060	16	32.546	4691	09:41	11:53	14:00	Megacore	7+3
D377-036	15/07/2012	AA1		48	57.607	16	32.706	4646	15:24	17:42	20:01	Megacore	7+3
D377-037	16/07/2012	CC1		48	57.792	16	33.534	4729	20:30	22:52	01:20	Megacore	7+3
D377-038	16/07/2012	PAP Central 1		48	50.312	16	31.106	4844	02:54	05:07	07:32	Megacore	7+3
D377-039	16/07/2012	AESA area	M52	48	59.357	16	35.024		12:56		22:50	Autosub6000	photo mission, no multibeam
D377-040	17/07/2012	DD2		48	59.881	16	35.150	4814	00:20	02:35	04:56	Megacore	7+3
D377-041	17/07/2012	PAP Central 2		48	50.109	16	30.897	4844	06:45	08:59	09:05	Megacore	7+3
D377-042	17/07/2012	PAP Central 2		48	50.124	16	30.888	4845	12:24	14:50		Boxcore	not fired
D377-043	17/07/2012	AESA area	M53						19:37		***09:00***	Autosub6000	photo mission, no multibeam
D377-044	18/07/2012	PAP Central 3		48	49.998	16	31.195	4845	00:02	02:10	02:13	Boxcore	successful
D377-045	18/07/2012	PAP Central 1		48	50.334	16	31.129	4844	10:38	12:45	14:00	Boxcore	successful
D377-046	18/07/2012	PAP Central 2		48	50.122	16	30.901	4845	16:48	19:01	21:30	Boxcore	successful
D377-047	19/07/2012	AESA area	M54						00:15	02:18	13:15	Autosub6000	photo mission, no multibeam
D377-048	19/07/2012	PAP Central 3		48	49.956	16	31.218	4845	15:50	18:09	20:38	Megacore	7+3
D377-049	19/07/2012	AESA area	M55						22:45	23:02	***00:05***	Autosub6000	photo mission, no multibeam
D377-050	21/07/2012	PAP Cent./AESA	M56	48	50.700	16	30.990		09:17		***04:30***	Autosub6000	photo mission, with multibeam
D377-051	21/07/2012	AESA area							14:02	16:48	23:45	SHRIMP	over summit
D377-052	22/07/2012	AESA area		49	2.090	16	32.500		08:30	08:41	08:46	CTD	with LSS sensor, aborted
D377-053	22/07/2012	AESA area		49	2.090	16	31.960	4840	12:07	12:07	13:12	CTD	with LSS sensor
D377-054	22/07/2012	AESA area	M57						15:06		22:06	Autosub6000	photo and multibeam mission
D377-055	23/07/2012	Goban Spur		49	35.423	11	50.843	993	16:24	17:12	18:04	CTD	for experiments
D377-056	23/07/2012	Goban Spur		49	35.517	11	50.872	996	18:50	19:27	19:50	Megacore	6 tubes, for experiments
D377-057	23/07/2012	Goban Spur		49	35.521	11	50.828	995	20:24	20:58	21:45	Megacore	6 tubes, for experiments
D377-058	23/07/2012	Goban Spur		49	35.424	11	50.733	994	22:02	22:39	23:20	Megacore	6 tubes, for experiments
D377-059	23/07/2012	Goban Spur		49	35.426	11	50.847	992	23:40	***00:10***	***00:40***	Megacore	6 tubes, for experiments
D377-060	24/07/2012	Goban Spur		49	35.488	11	50.816	992	01:04	01:34	02:10	Megacore	6 tubes, for experiments
D377-061	24/07/2012	Goban Spur		49	35.476	11	50.793	992	02:20	02:49	03:20	Megacore	6 tubes, for molecular work
Coprolite	24/07/2012	Whitard Canyon		48	25.680	9	56.980				14:00	Glider	FASTNEt glider
D377-062	25/07/2012	Haig Fras area	M59					100	17:42		***10:50***	Autosub6000	acoustic and photo mission

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