JC077 2ND - 28TH September 2012

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National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

UNIVERSITY OF Southampton

ECO2

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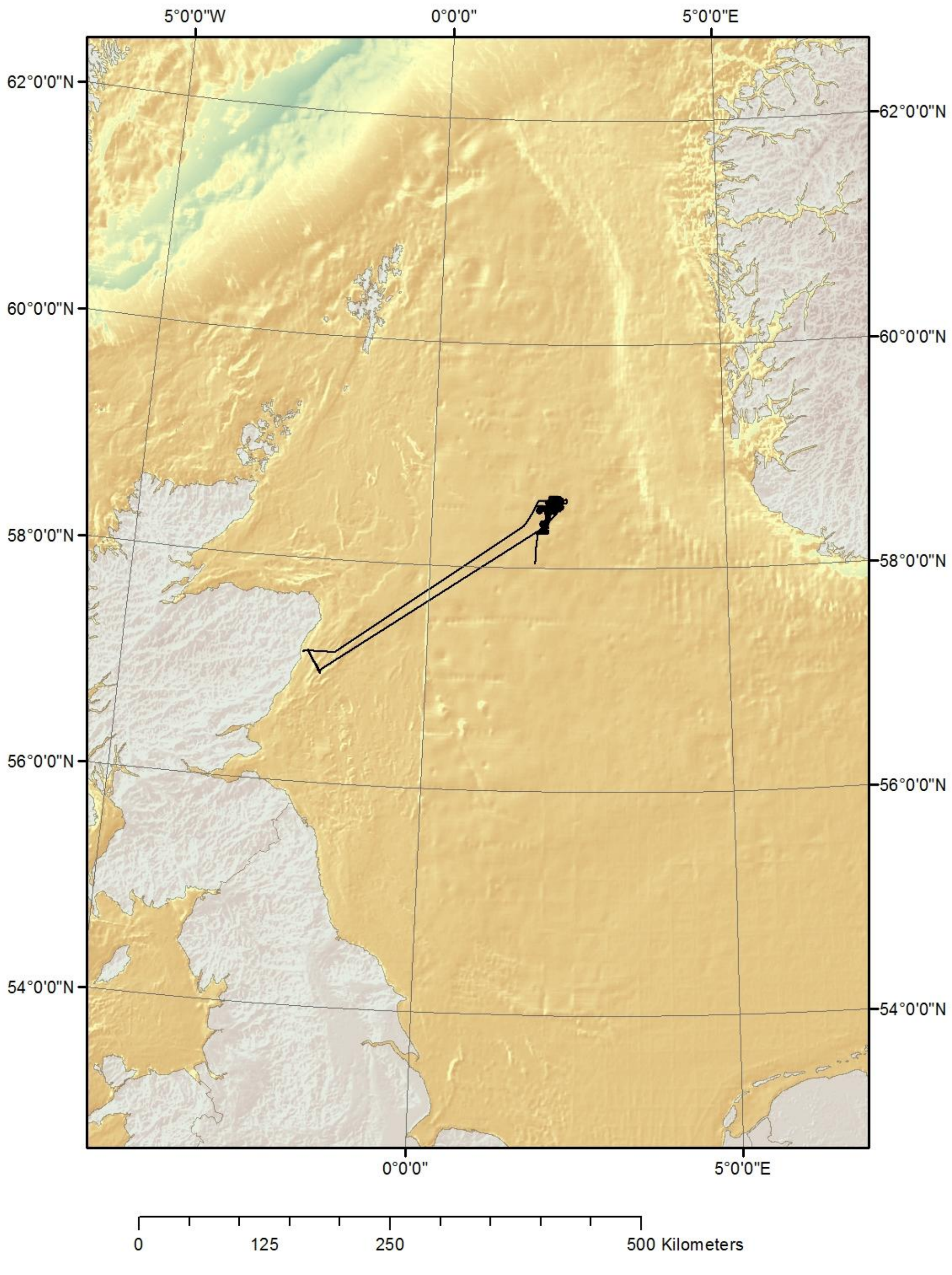
Introduction

The NOC lead cruise, JC077 represents the main cruise activity as part of the UK's input to the EC funded ECO_2 project. The project aims to develop a "Best environmental practice" for the carbon capture and storage (CCS) industry. CCS has been proposed as a means of mitigating climate change by storing CO_2 in geological reservoirs. The UK has identified sub-seabed storage as the most likely CCS process to be used. Other countries such as the US and Germany are pursuing land based CCS geological storage. Two types of reservoirs have been identified, saline aquifers such as Sleipner or depleted hydrocarbon reservoirs (oil and gas fields). The storage process require a monitoring strategy to ensure that any storage site is effectively monitored to ensure no leakage, or if there is leakage, to detect and monitor the effect of that leakage on the marine environment.

The Sleipner site in the Norwegian sector of the North Sea is one of the longest operated CCS sites in Europe. It uses CO_2 that has been separated from the natural gas from the Sleipner West Field and injects it into a saline aquifer in a permeable sand body called the Utsira sand. The aquifer is capped by a seal of shale and is thought to be impermeable. The depth of the aquifer is 900 m below the seafloor with 80m of water. This storage site has been in operation since 1996 and contains more than 14 million m^3 of CO_2 with more being continually added. The site has been monitored mainly through the use of seismic on regular intervals to produce "4D" maps of the distribution of the CO_2 though the reservoir. These models show a migration of the plume of CO_2 to the north west.

JC077 takes a multidisciplinary approach to assess the Sleipner area for signs of leakage from the existing CCS reservoir. We will use a combination of AUV technology with a suite of sensors to determine if leakage is already occurring from the Sleipner field and if so to examine the effects of such leakage. The use of the AUV Autosub allows us to survey areas of the seabed at a resolution that is simply not possible by other means over a comparable time frame. The newly developed pH, pCO2 and Eh sensors attached to Autosub allow us to detect sites of leakage if it occurring. Chirp and sidescan sonar mounted on Autosub would also allow the identification of sub-seabed and seabed features of interest. In conjunction with this we will use ship based multibeam and EK60 to look for leakage sites, and use water and sediment sampling systems to examine the state of the environment at present, and examine any areas of leakage detected.



Track line plot of Cruise JC077. September 2nd to September 28th 2012.

Scientific Party

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J. M. Bull	UoS	Marine Geophysicist
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A. Lichtschlag	NOCS	Geochemist
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E. McDonald	UoS	MSc. Student
C. Millar	UoS	MSc Student
J. Pheasant	BGS	Marine Engineer
C. Richardson	BGS	Apprentice Engineer
K. Shitashima	Uni. Kyushu	Sensor Scientist
D. Wallis	BGS	Marine Engineer

Technical Team

J. Evans	NOCS	Technical Liaison Officer
D. Childs	NOCS	CTD Specialist
G. Knight	NOCS	IT Specialist
S. D. McPhail	NOCS	Autosub Specialist
D. Paxton	NOCS	Autosub Engineer
R. Roberts	NOCS	Marine Engineer
T. Roberts	NOCS	Marine engineer

Ships Company

J. Leask	Master	S. Day	POD
J. Gwinnell	Chief Officer	G. Crabb	Able Seaman
V. Laidlow	2nd Officer	J. Dale	SG1A
P. Munro	3rd Officer	P.Alford	SG1A
G. Parkinson	Chief Engineer	A. Osborne	SG1A
C. Uttley	2nd Engineer	I Cantlie	SG1A
G. O'Sullivan	3rd Engineer	B. Conteh	ERPO
D. Clark	ETO	D. Caines	Head chef
M. Rogers	J/ETO	M. Ashfield	Chef
P. Lucas	PCO	G. M. Mingay	Steward
S. Smith	CPOS	C. McLaughlin	Asst. Steward
P. Allison	CPOD		

Acknowledgements

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CONTENTS

Section 1. Daily Operations

2/9/12
Departed Southampton

3/9/12
Turned on Multi-beam system logging

5/9/12
Arrived on station "Southern Chimneys" site. Did a multibeam/EK60 survey. Did Autosub deployment. Steamed to "Middle Area". Did a trial CTD deployment. Did multibeam survey of Middle Area. Left to pick up AUV.

6/9/12
Continued MB survey of Southern chimney while waited for AUV recovery. Recovered AUV. Continued multibeam. MB survey over the Northern Fracture.

7/9/12
Did survey over Northern Fracture. Deployed AUV over Middle Area. Started MB survey over site 3. Moved to Northern Fracture. Did CTD (JC077-CTD002) in Northern fracture area over bacterial mats identified by Geomar this summer. Did two vibrocores and got good recovery. Recovered AUV from Middle Area. Did multibeam to fill gaps over Northern Fracture.

8/9/12
Finished multibeam then did 2 CTD's and three vibrocores, in the Northern Fracture area. Deployed Autosub early evening for a survey over the Northern Fracture. Started a multibeam.

9/9/12
R/V Merion kindly deployed the seafloor lander at 0715 GMT at 58°35.76 N, 02°5.34 E. We recovered AUV, then three CTD's along the Northern fracture and 3 vibrocores.

10/9/12
Started day with Multibeam survey. Recovered AUV. Two CTD's and a vibrocore done over the Northern Fracture area. Multibeam mini-survey followed by AUV deployment over the Middle Area. Continued multibeam.

11/9/12
Recovered AUV and did two CTD's. Started multibeam but weather picked up. Suspended science and steamed towards Aberdeen to pick up Veit Huhnerbach.

12/9/12
Hove too off Aberdeen.

13/9/12
Off Aberdeen storm out at sea.

14/9/12
Left Aberdeen in morning to return to study area. Seas rough and we were delayed in arriving. Multibeam survey over the modelled plume spreading area.

15/9/12
Did a multibeam survey over the spreading plume area. Did a series of 8 CTD casts across the south, centre and northern part of the spreading plume area. Did two vibrocores at the Northern Fracture area. Deployed Hybis over the site the Merien deployed the NOCS lander. Deployed AUV over western Northern Fracture.

16/9/12
Multibeam over Northern Fracture. CTD over wellhead 16/4-2. Recovered AUV. Vibrocored at the wellhead area. Deployed Hybis on the wellhead.

17/9/12
Started with multibeam and did CTD over the bubble plume area located by Hybis. Megacores from same site. Vibrocore sample collected over plume spreading area, deployed AUV same area. Hybis deployment over Middle Area. Multibeam over plume spreading area.

18/9/12
Finished multibeam survey and then a CTD on the Middle Area. Did megacore and two vibrocores in the same area. AUV deployment cancelled due to weather. Multibeam over the plume spreading centre.

19/9/12
Finished multibeam. Did a series of CTD's over the anomaly areas on the Middle Area. Weather closed in and had to stop. Tried to launch AUV, but weather too poor. Did Hybis when weather started to get better in early evening. Multibeam over the spreading area.

20/9/12
Finished multibeam and did AUV deployment over the Middle Area.

21/9/12
Started with multibeam. Many CTD casts over Middle Area. Vibrocore and megacore samples collected. Deployed AUV. Multibeam survey through the night.

22/9/12
Finished multibeam survey and recovered AUV. Did CTD survey over Middle Area. Vibrocore and megacore samples collected at Middle and Northern Fractures. Deployed AUV. Did megacore sampling over Northern fracture.

23/9/12
Did CTD's to get a regional view and fill gaps in our study areas. Collected the AUV and did vibrocores over the Northern Fracture. Did more CTD's then had to leave study area because of a very big storm coming.

25/9/12

Weather still poor. Did one background CTD.

26/9/12
Did a multibeam survey off Flamborough Head. Did additional background CTD in shallower water.

End of Science. Returning to Southampton.

Station numbers used during JC077

1. **Southern Chimneys**
2. **Middle Area**
3. **Bubble site well number 15/9-11**
4. **Well head 15/9- 16**
5. **Northern Fracture**
6. **Area between Northern fracture and Middle Area**
7. **Fill between Northern fracture and Middle Area.**
8. **Fill in between MC and BC**

Section 2. Sites of Investigation

Melis Cevatoglu and Jonathan Bull

Several sites chosen for fluid flow investigation during JC077 cruise were the target of Autosub 6000 science missions (see the table summarizing key information for each mission).

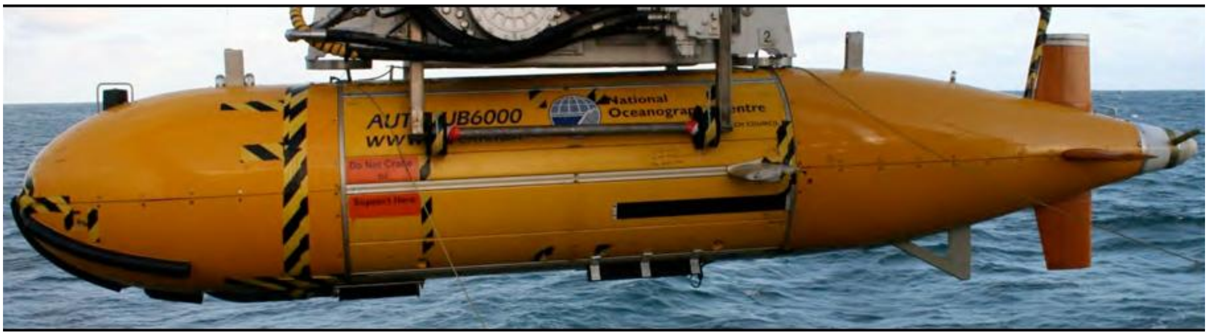


Figure 2.1. Autosub 6000

1- Southern Chimneys

The 3D seismic data collected by Statoil (1998) reveals the presence of seismic chimneys in the sediments, 6 km south of the Sleipner platform (Jens Karstens, personal communication, 2012). These vertical fluid pathways cause strong amplitudes anomalies on the seismic data. Therefore, this site was the target of Autosub M59.

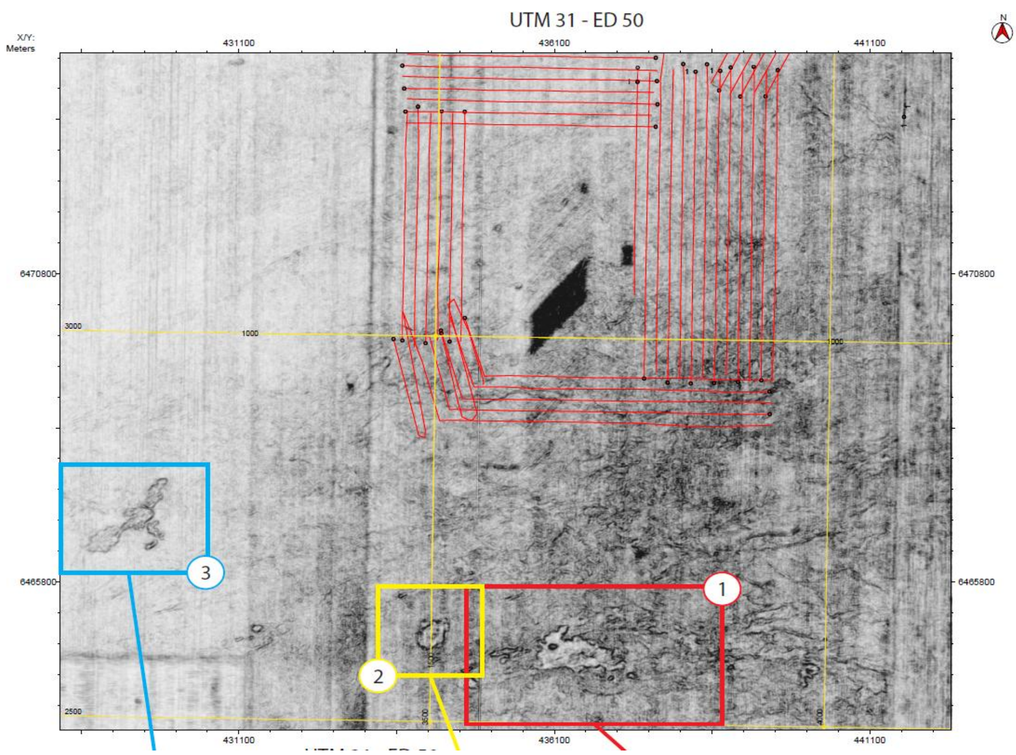


Figure 2.2. Seismic chimneys on the south of the Sleipner platform (Jens Karstens, 2012)

2. Middle Area

A similarity analysis of Statoil 3D seismic data (Jens Karstens, 2012) reveals relatively shallow possible fractures or paleochannels in the sediments, 18km north of the Sleipner platform. This observation led to several Autosub dives to the area (M60, M63, M67).

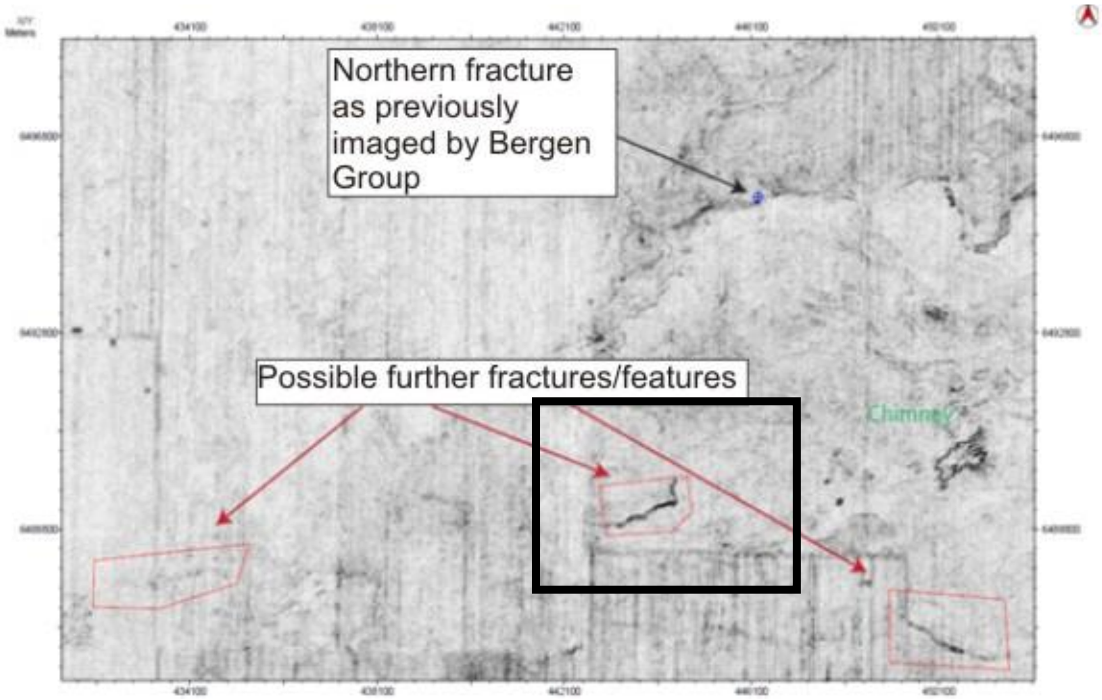


Figure 2.3. Possible fractures on the 18km north of the Sleipner platform with the black box indicating Middle Area (modified after Jens Karstens, personal communication, 2012)

3. Northern Fracture

Prior work completed by the University of Bergen in 2011 and 2012 revealed the presence of a 3km long fracture system c.25 km north of the Sleipner platform. During JC077 cruise, this fracture was intensively investigated in terms of its extent and activity (M61, 62, 64).

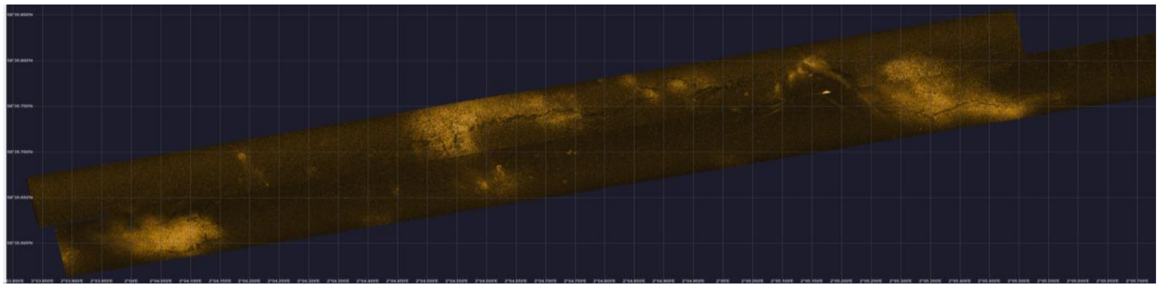


Figure 2.4. SAS image of the Northern Fracture, 2012 (University of Bergen)

4. CO_2 plume

In order to investigate possible fluid leakage from Sleipner CO2 storage site, several Autosub dives were completed over the C02 plume area (M65, M66).

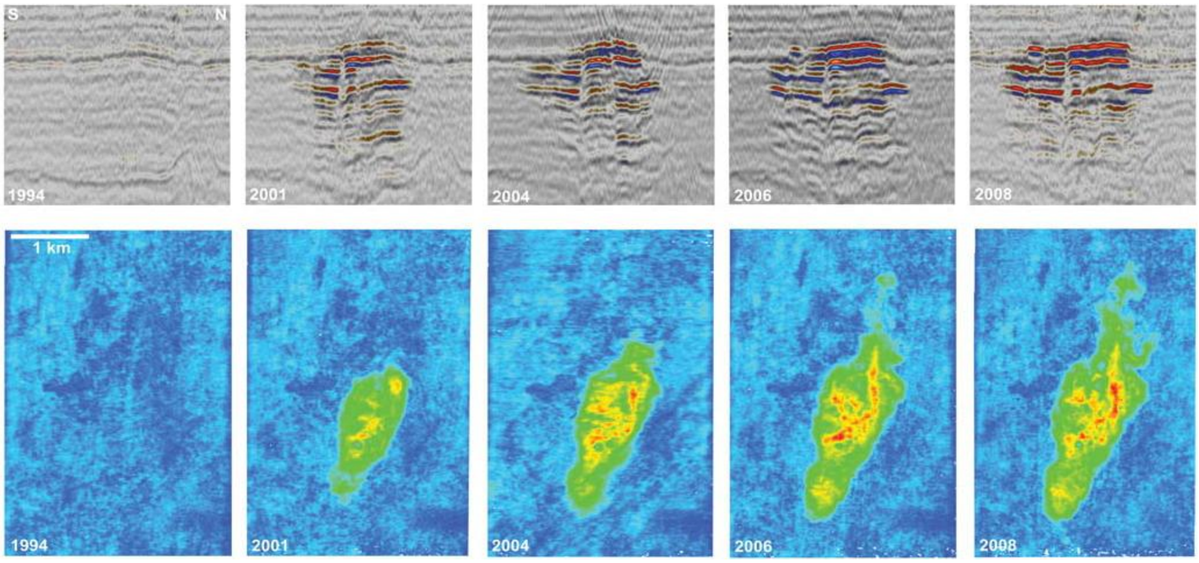


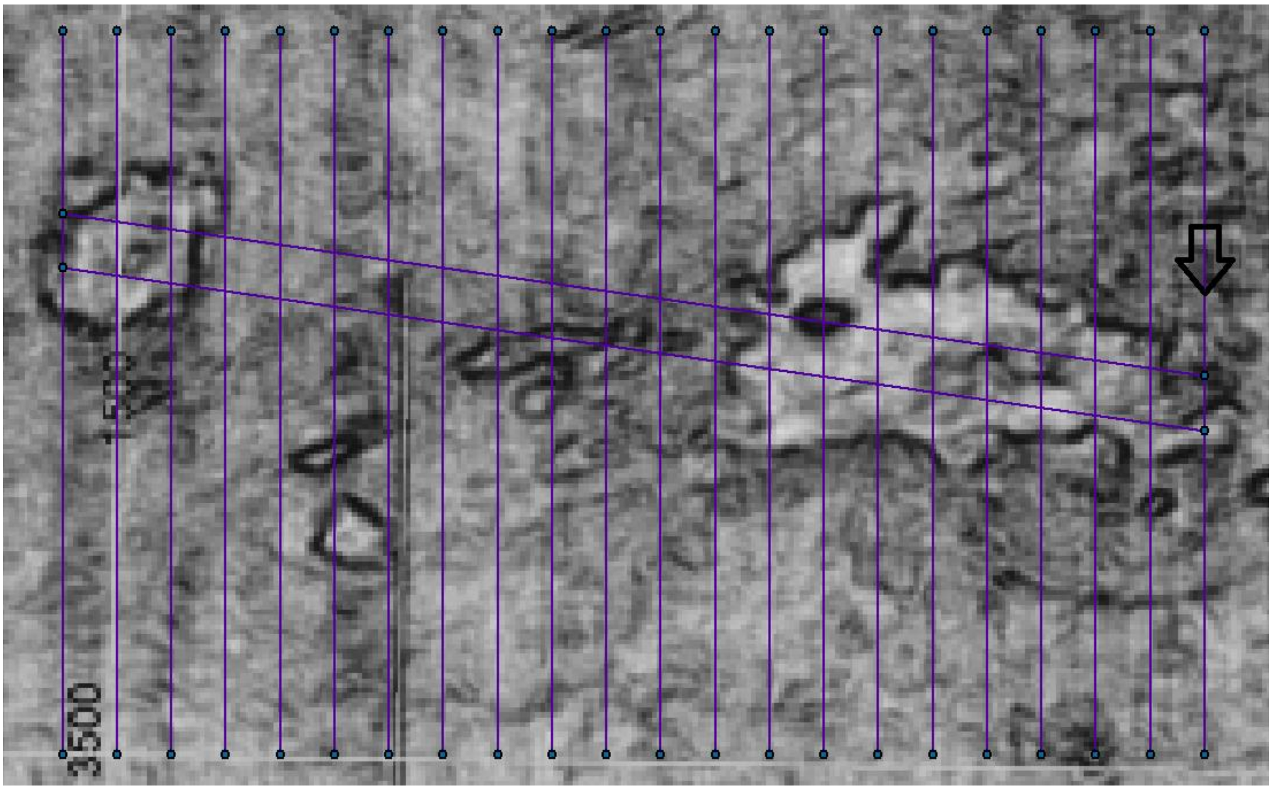
Figure 2.5. The growing CO2 plume (Chadwick et al, 2004)

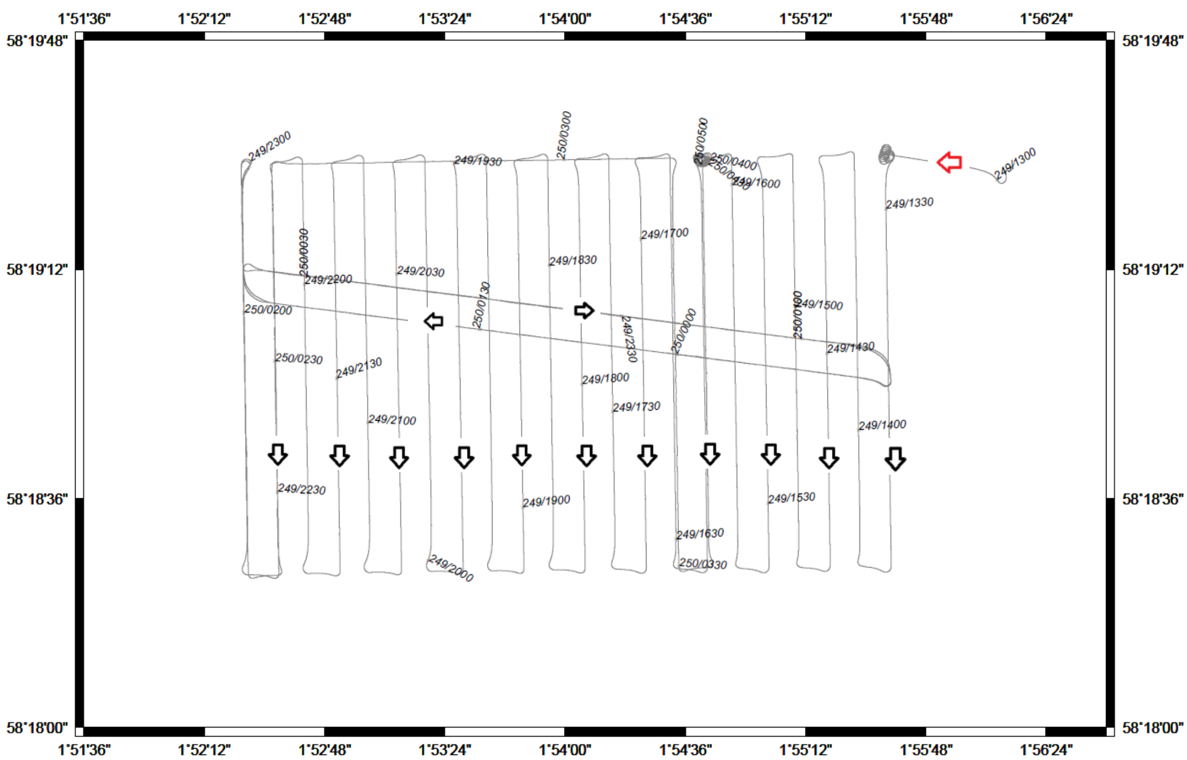
AUTOSUB DIVE	AREA	ALTITUDE	DAY	LINE SPACING	CORRUPTED DATA FILES
M59	SOUTHERN CHIMNEYS	12m	05/09/2012	150m	
M60	MIDDLE AREA	12m	07/09/2012	100m	42, 52,53, 56
M61	NORTHERN FRACTURE	12m	08/09/2012	150m	41
M62	NORTHERN FRACTURE	3m	09/09/2012	150m	40, 44
M63	MIDDLE AREA	3m	10/09/2012	50m	80
M64	WESTERN NORTHERN FRACTURE	12m	15/09/2012	150m	133, 169
M65	CO2 PLUME	12m	17/09/2012	150m	29, 32
M66	C02 PLUME	3m	20/09/2012	150m	77, 78
M67	MIDDLE AREA	4m	21/09/2012	50m	33, 101
M68	REGIONAL	12m	22/09/2012	1000m	117

Table 2.1. Summary of the Autosub Missions

M59 SOUTHERN CHIMNEYS:

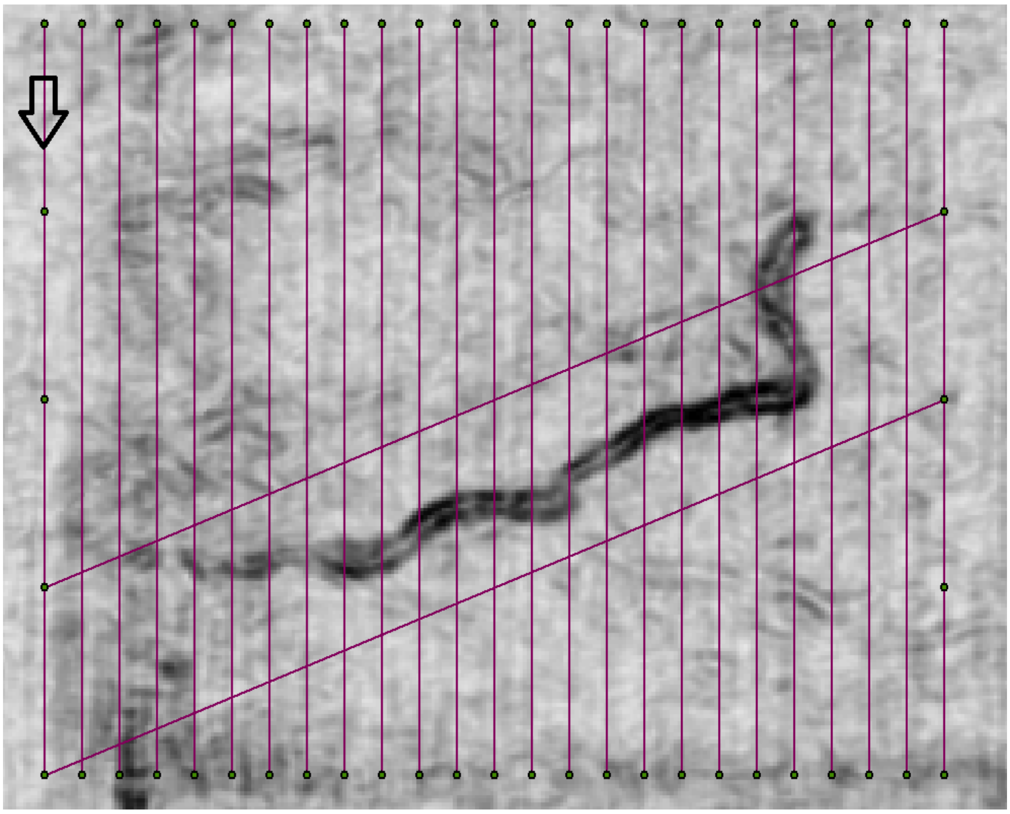
Altitude : 12 metres, Line Spacing : 150 metres

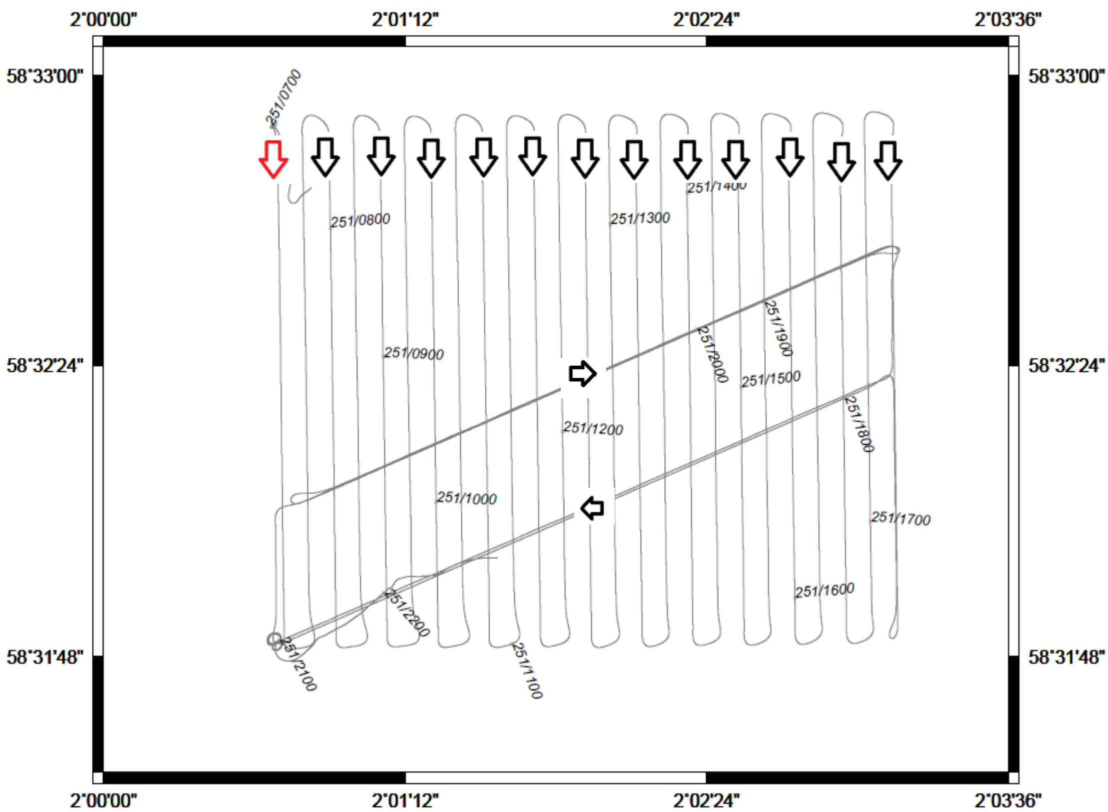




M60 MIDDLE AREA

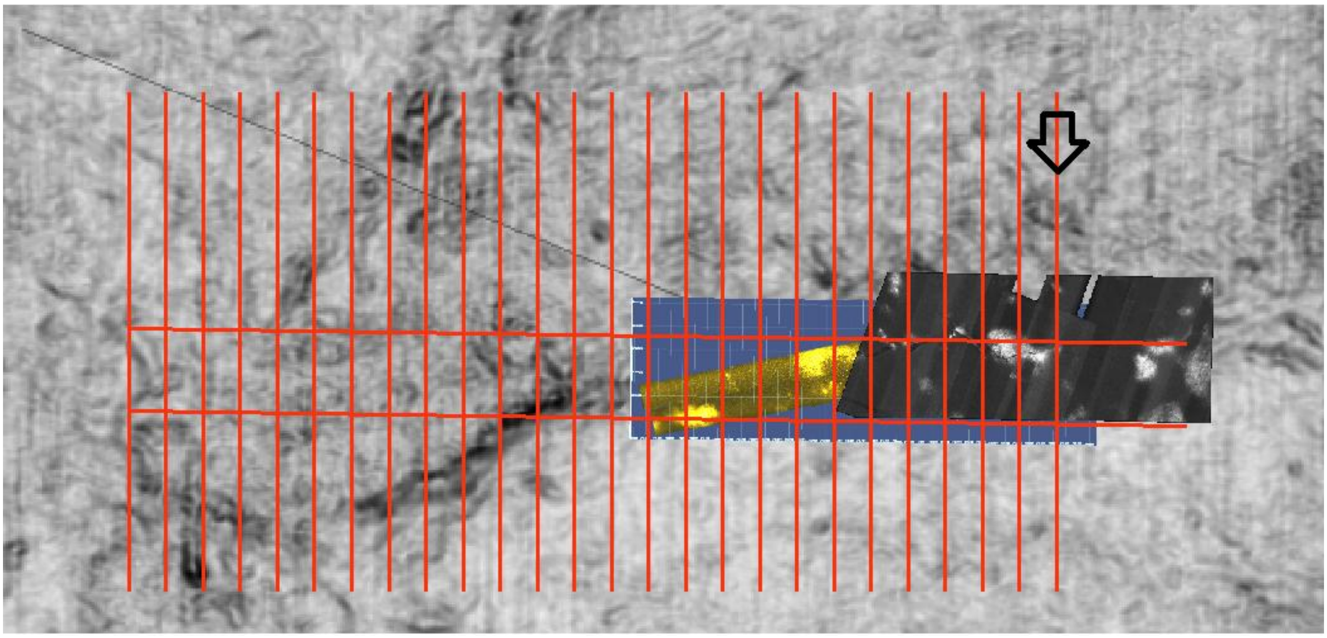
Altitude : 12 metres, Line Spacing : 100 metres

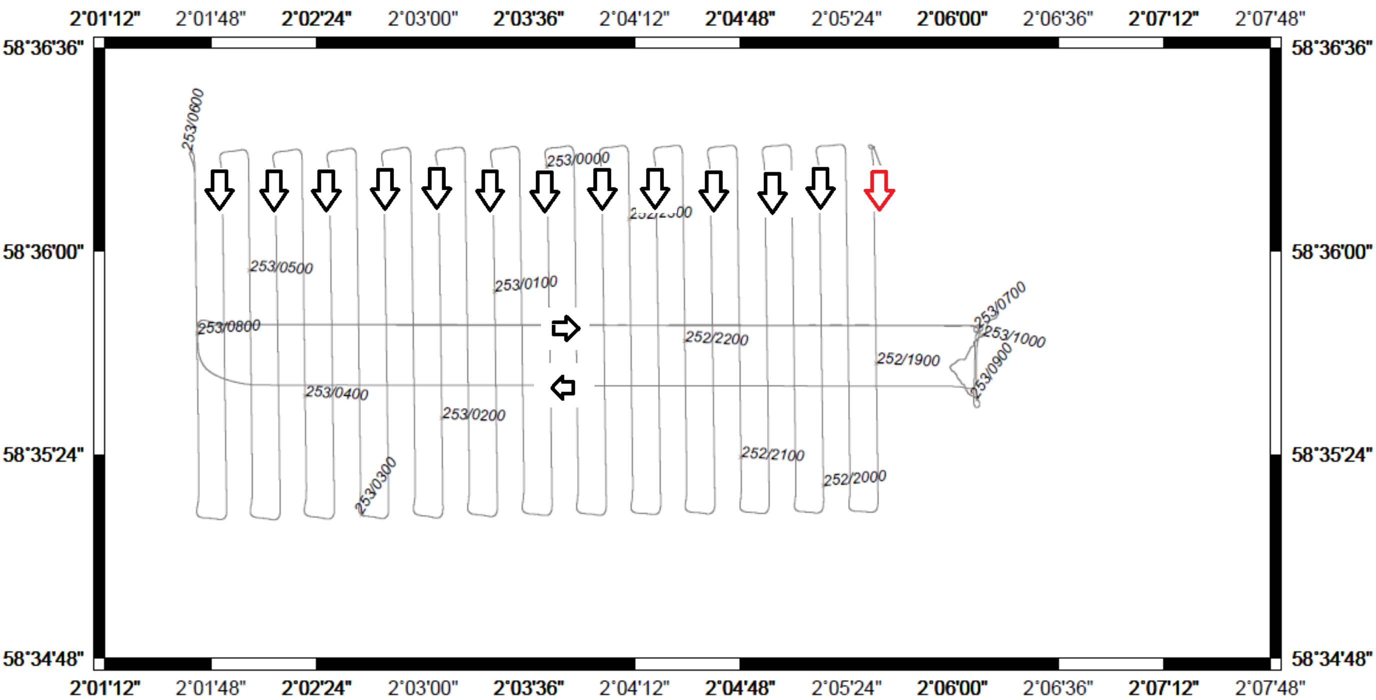




M61 NORTHERN FRACTURE

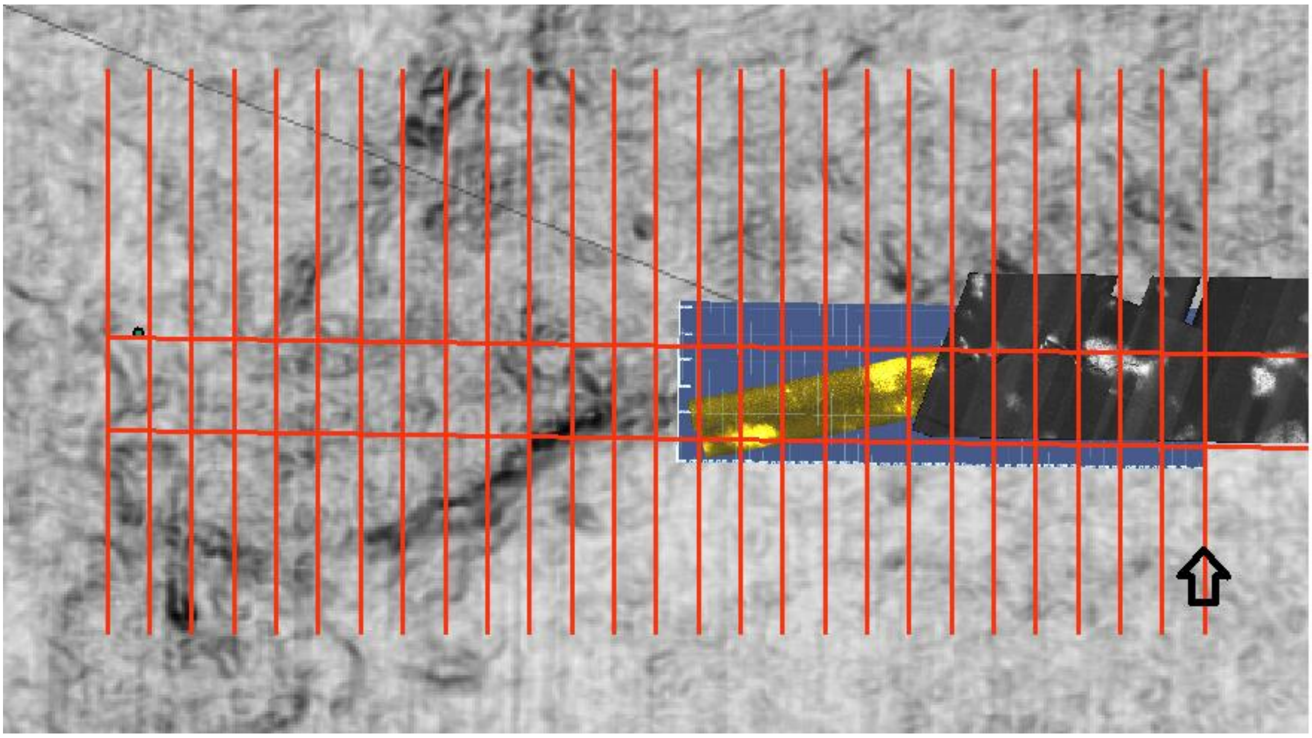
Altitude : 12 metres, Line Spacing : 100 metres

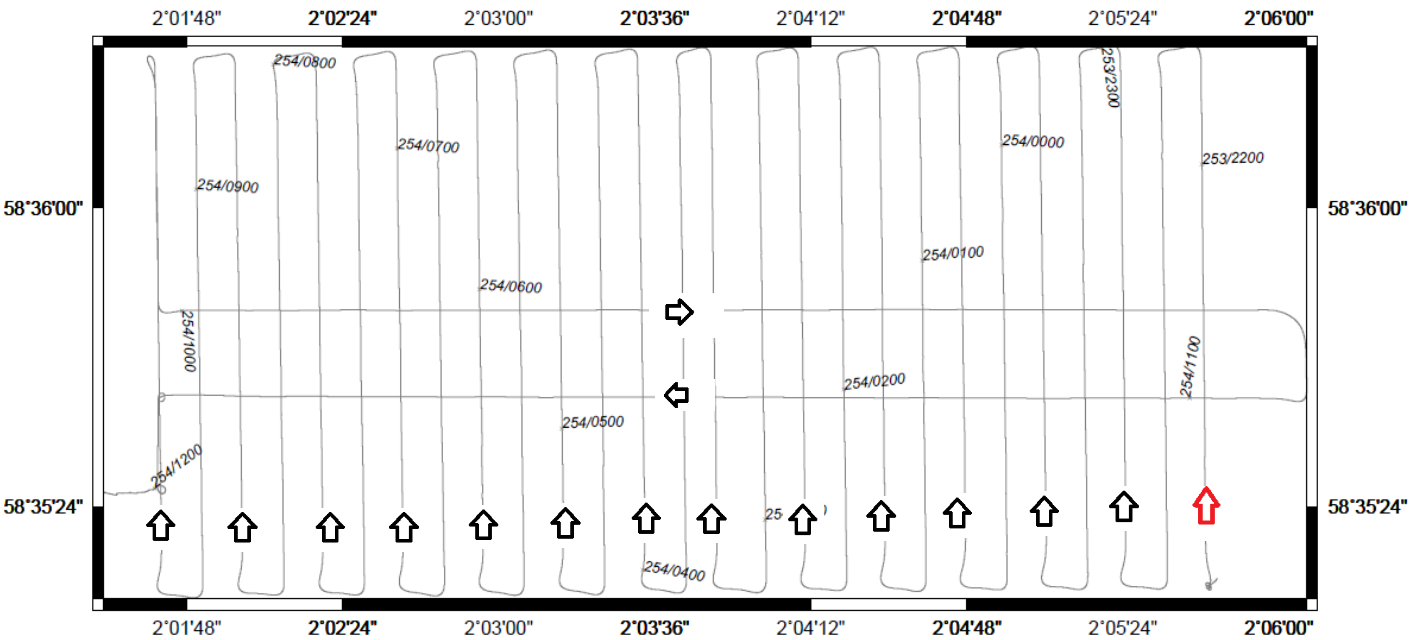




M62 NORTHERN FRACTURE

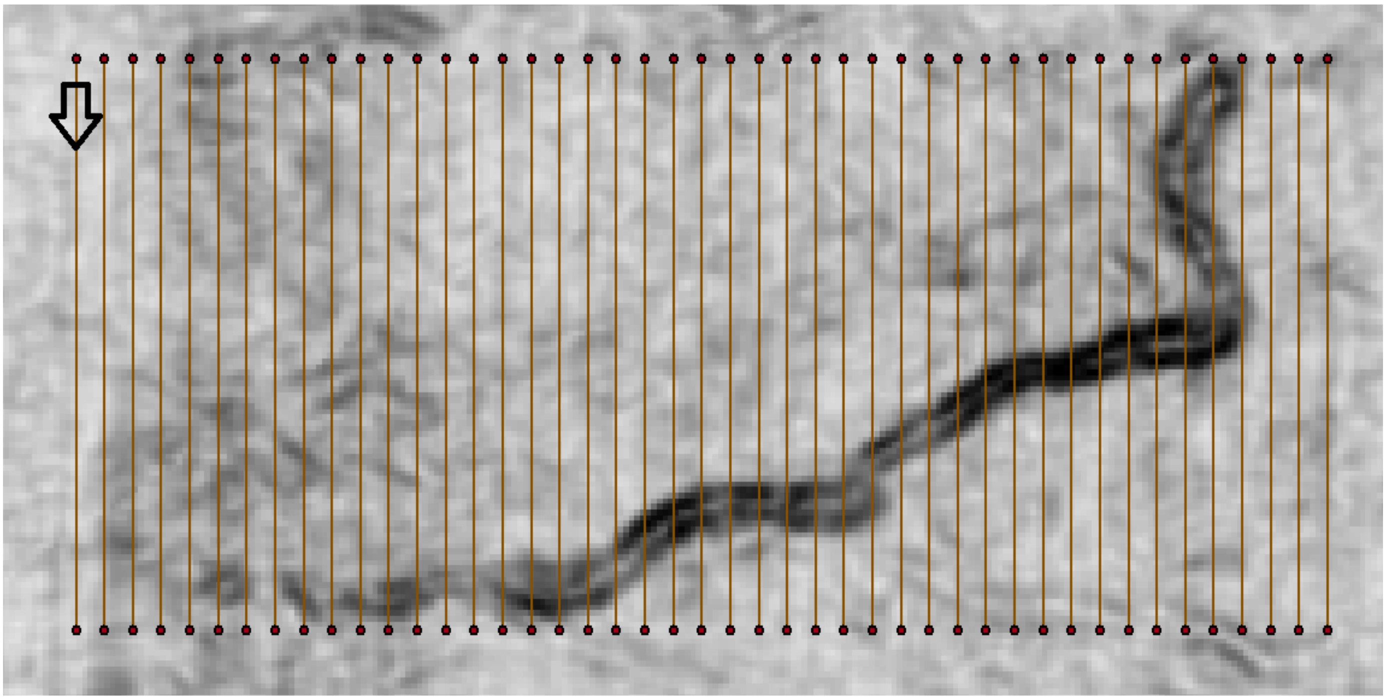
Altitude : 3 metres, Line Spacing : 150 metres

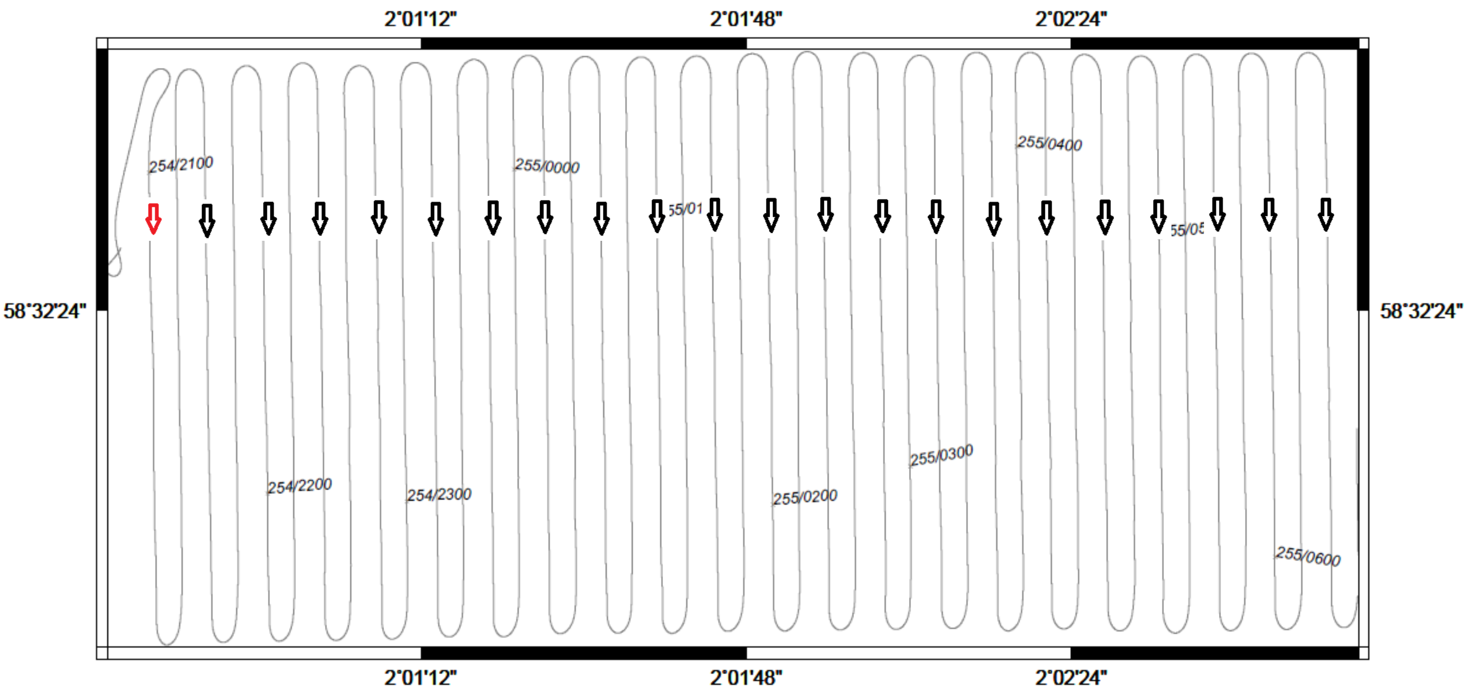




M63 MIDDLE AREA

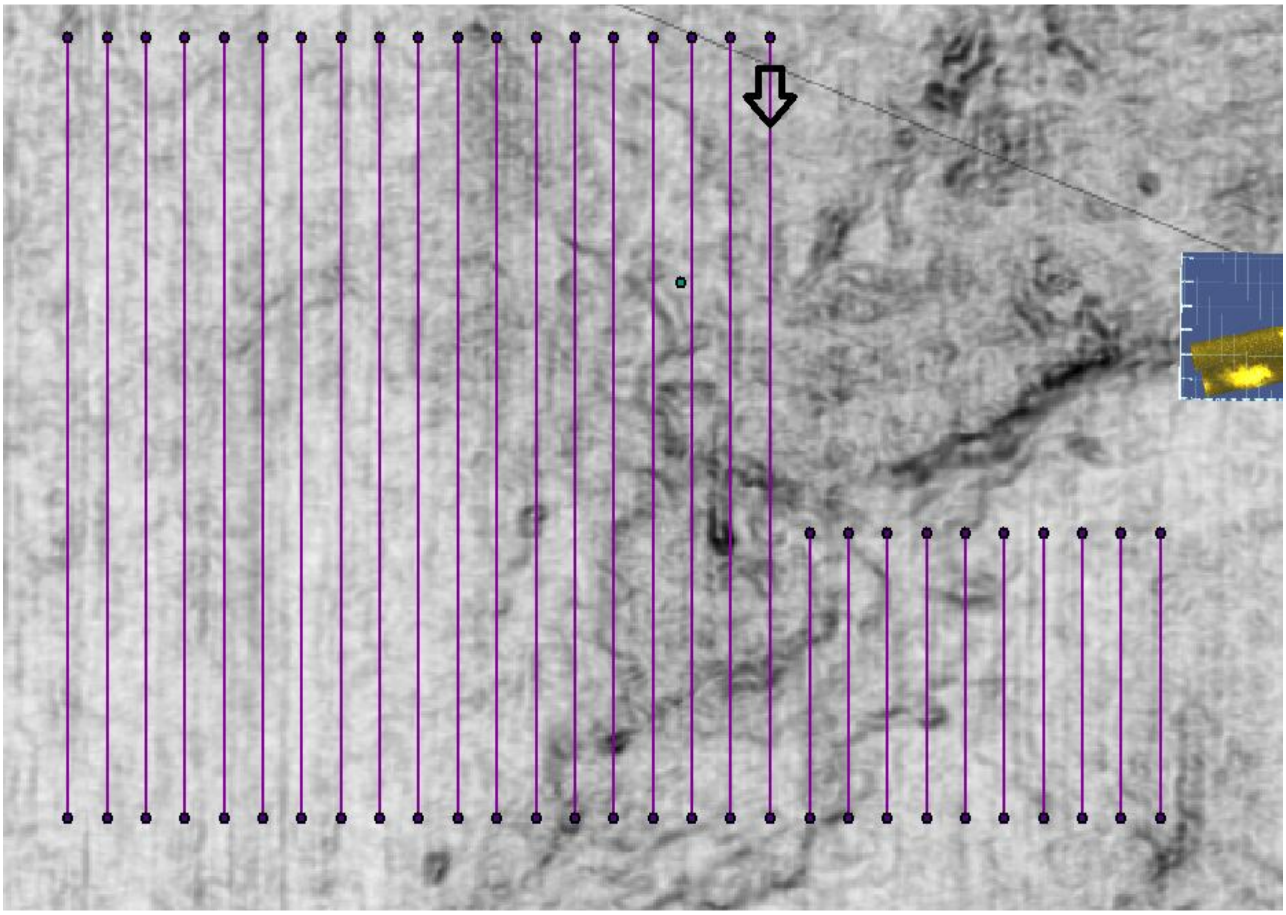
Altitude : 3 metres, Line Spacing : 50 metres

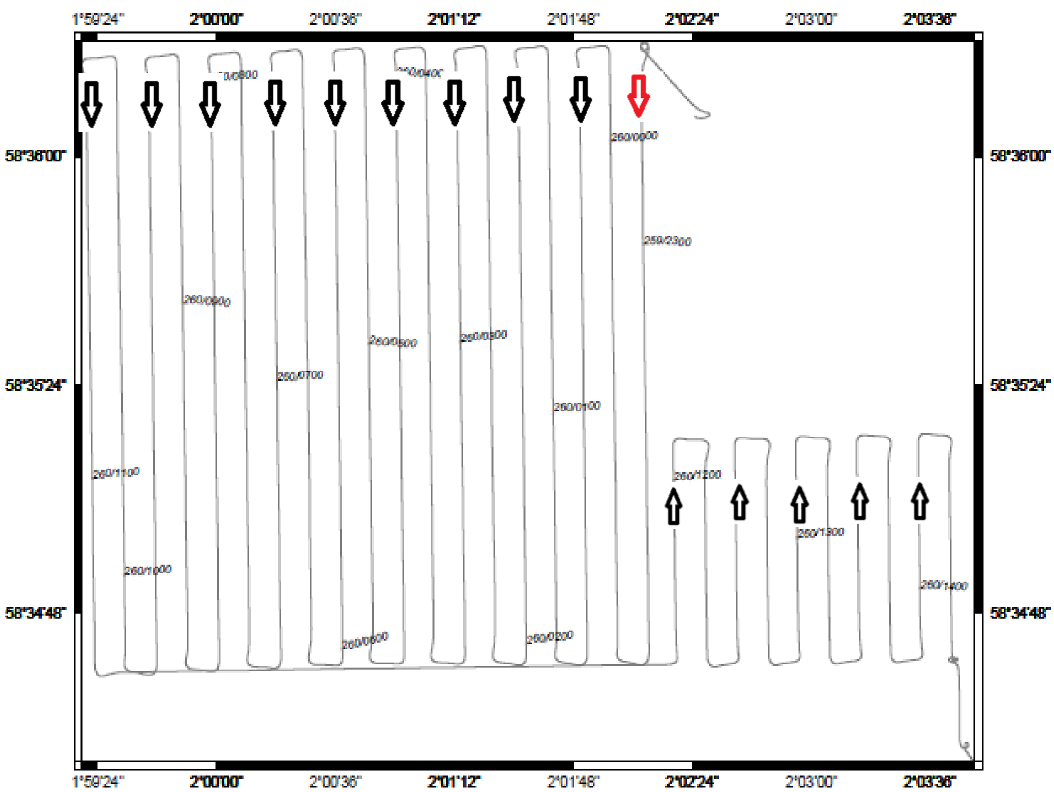




M64 WESTERN NORTHERN FRACTURE

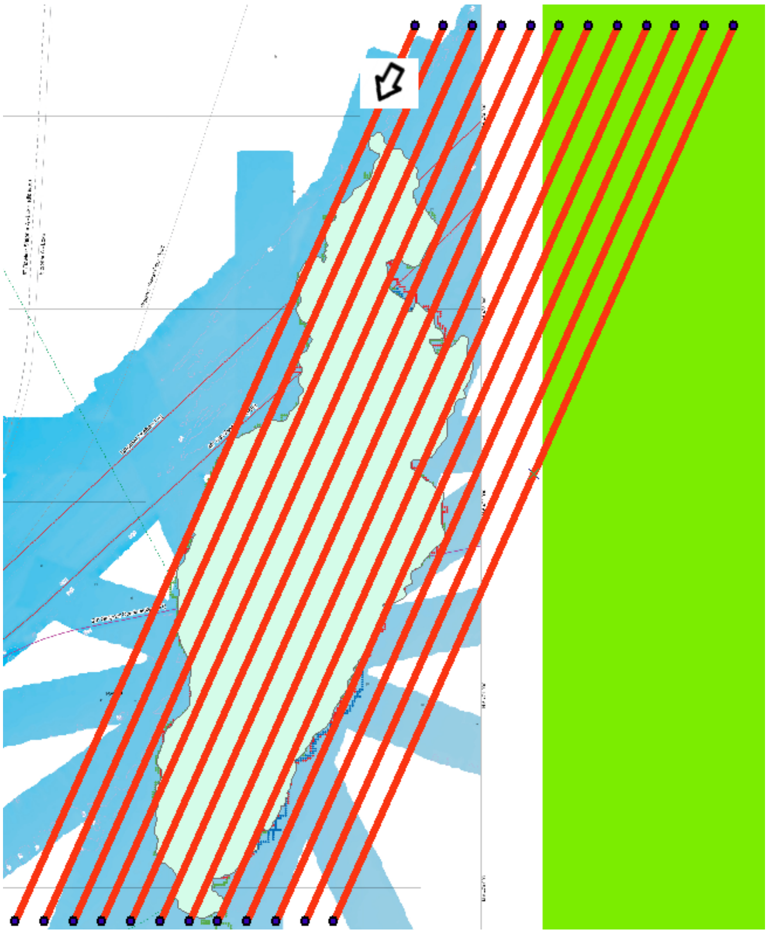
Altitude : 12 metres, Line Spacing : 150 metres

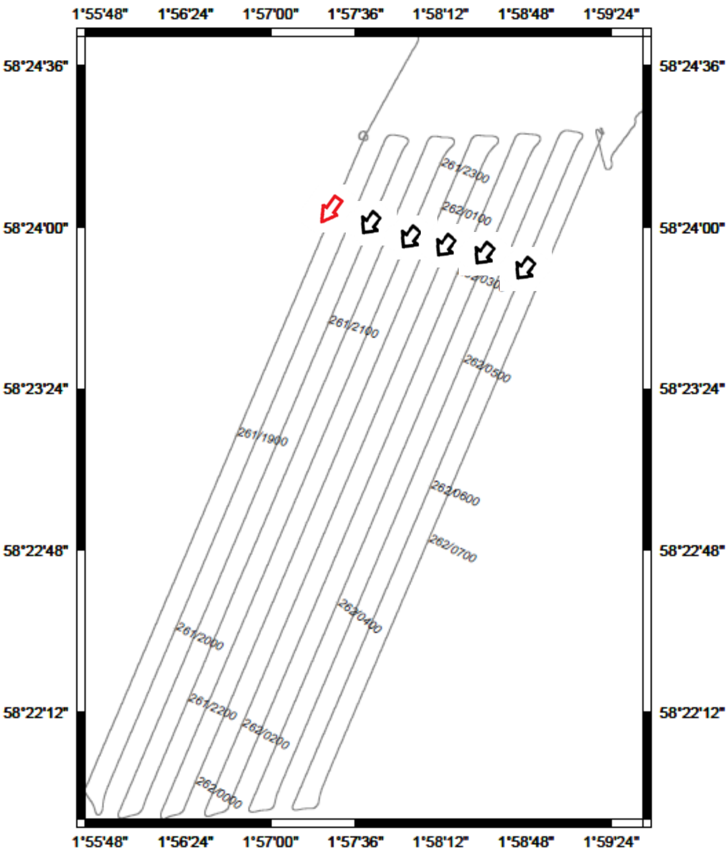




M65 CO2 PLUME

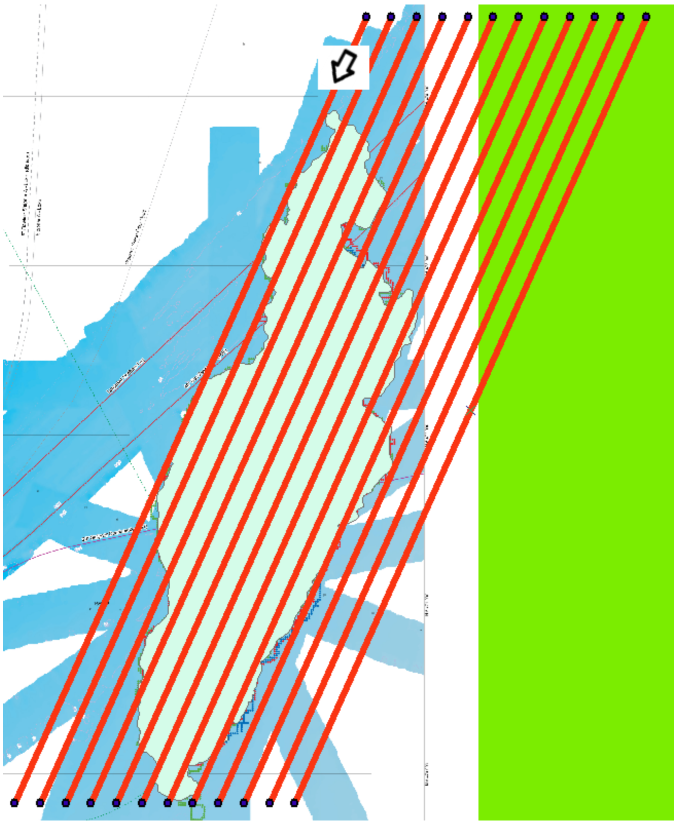
Altitude : 12 metres, Line Spacing : 150 metres

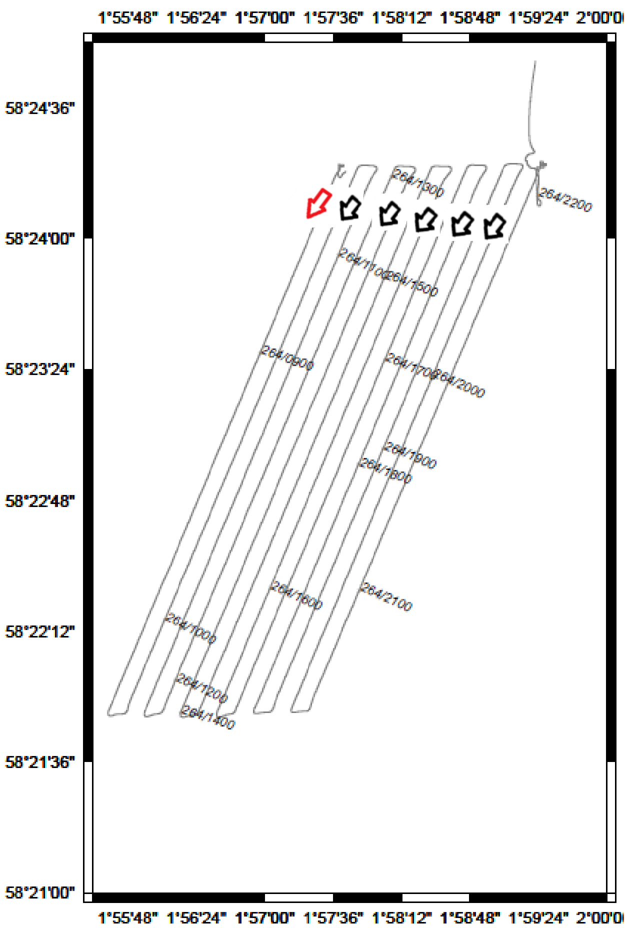




M66 CO2 PLUME

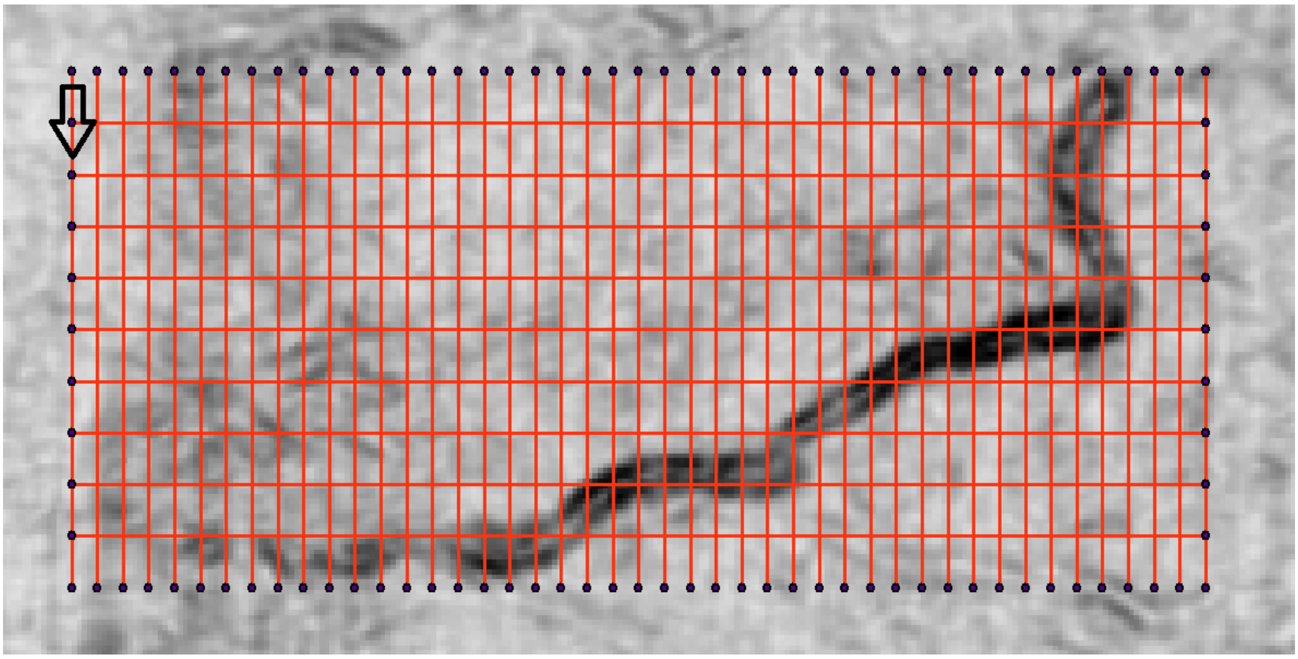
Altitude : 3 metres, Line Spacing : 150 metres

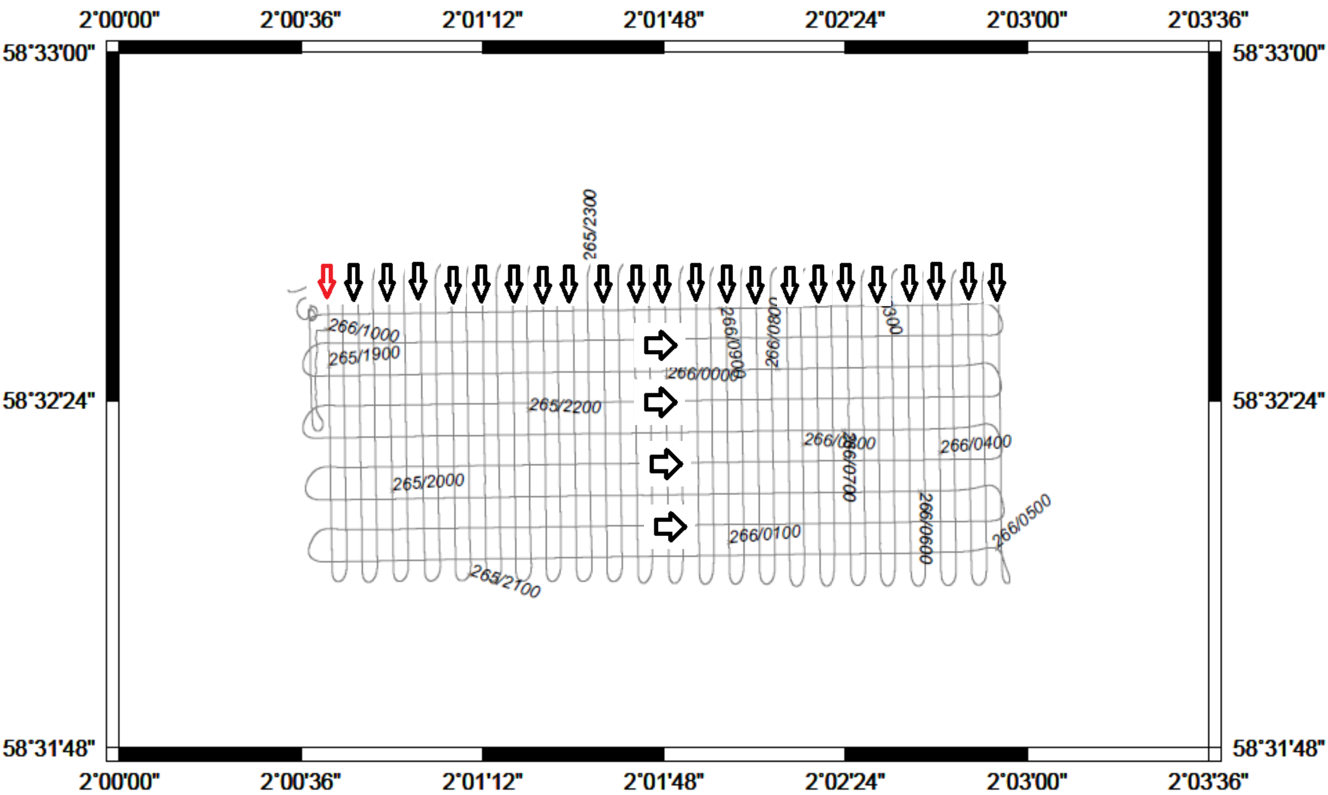




M67 MIDDLE AREA

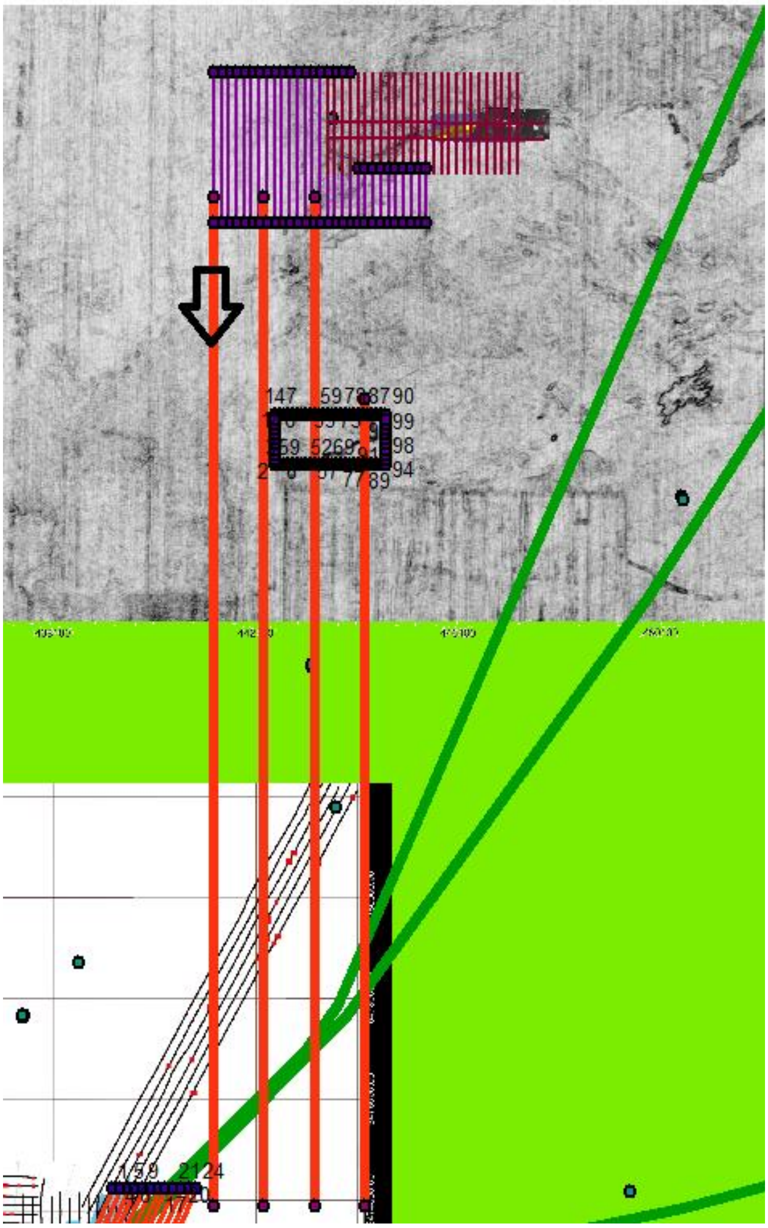
Altitude : 4 metres, Line Spacing : 50 metres

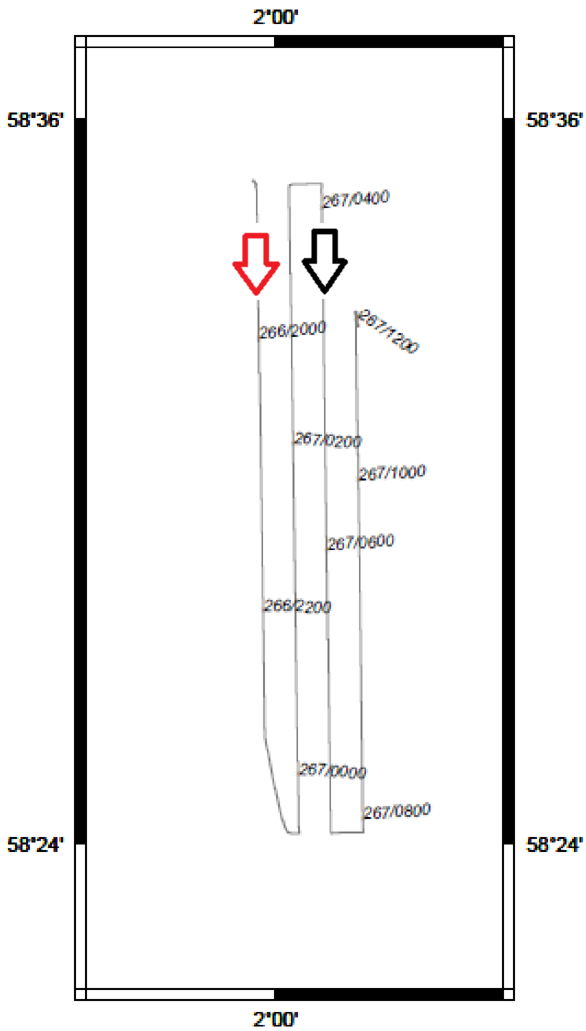




M68 BACKGROUND

Altitude : 12 metres, Line Spacing : 1000 metres





Autosub Seismic Data Features and Processing Steps

The Edgetech 2200-M Modular Sonar System mounted on Autosub records the data in jsf format. The seismic data is recorded on two channels: raw (uncorrelated) and analytic (correlated) data. The source sweep used during seismic data collection was a high frequency chirp signal oscillating between 2-13 kHz with sine squared 8th envelope and 32ms length. Depending on the altitude of the Autosub (3-4m or 12m), the penetration for all missions varies between 2.5 and 3.5m below the seabed.

The seismic data was pre-processed on board. The processing consists of several stages which can be classified such as:

- Importing navigation, altitude, depth, pitch, roll, heading information in seismic data headers
- Converting Edgetech jsf format to segy format
- Correlation of the raw data with the source sweep
- True amplitude recovery
- Importing processed data in Petrel Seismic Interpretation Software

<u>Importing Autosub parameters</u>

Once the jsf data is copied from Autosub, several parameters were merged in each jsf file headers by means of Matlab.

JsfFileWiever can be used to check the data quality after this process.

<u>Converting jsf to segy</u>

The data was converted from jsf to segy using the jsf2segy software.

The jsf2segy package is a free software, written by Tom O'Brien (USGS, Woods Hole Coastal and Marine Science Center) in 2004, with last update in 2005. It allows the conversion of Edgetech jsf 512i seismic data format to SEGY Rev_1. This section briefly describes different components, summarizes necessary actions that should be taken in order to convert properly jsf format into segy, with special emphasis on different steps regarding the compilation of the code.

1) <u>Introduction to different components</u>

Once the package is downloaded from the website (http://sioseis.ucsd.edu/), the user notices that four different folders are present: jsf2segy, lstjsf, msg80, msg82. Each folder has different purposes:

⇨ Jsf2segy is the main folder allowing the conversion of jsf format into segy format.

⇨ Lstjsf permits to check total numbers of records, lists different data channels (formats) present in a jsf file: envelope, raw (uncorrelated), analytic (correlated) or real for sub-bottom; port and starboard for sidescan) and provides a few parameters of the jsf file header.

⇨ Msg80 and Msg82list some elements of Edgetech message 80/82 jsf files. They allow the visualization of the total number of records on the jsf input file, as well as list Side Scan Sonar and Sub-bottom message headers in a more complete way.

2) <u>Initial commentary</u>

If the user has some prior knowledge about the content of the data collected and/or has got JsfFileViewer Application (developed by Edgetech itself) to investigate the input file, the usage of lstjsf, msg80 and msg82 can be skipped. Otherwise, in order to be able to check if the data is converted properly from jsf to segy, the input jsf file should be analysed using these three tools.

3) <u>Compilation of the code</u>

Although the code is ready, it should be compiled under a Unix-like environment. To accomplish the compilation, the user needs to have a look to "Makefile", present in each folder: it describes how to compile the related code:

Jsf2segy: gcc jsf2segy.c ascebc.c utils.c –g –m32 –lm –o jsf2segy (compilation of jsf2segy.c creates jsf2segy command)

Lstjsf: gcc lstjsf.c utils.c –g –m32 –lm –o lstjsf (compilation of lstjsf.c creates lstjsf command)

Msg80: gcc msg80.c utils.c –g –m32 –lm –o msg80 (compilation of msg80.c creates msg80 command)

Msg82: gcc msg82.c utils.c –g –m32 –lm –o msg82 (compilation of msg82.c creates msg82 command)

4) <u>Work with the code</u>

Once the code is compiled, it is sufficient to type commands recently created on the terminal. This shows how to use the command and its applications.

<u>jsf2segy</u>

mc4g11@sarge.noc.soton.ac.uk>jsf2segy

jsf2segy ... extracts sub-bottom data from Edgetech JSF formatted files

Usage: jsf2segy - options first then full path to input file name

Options -e Get Envelope sub-bottom data

-a Get Analytic (correlated) sub-bottom data and make Envelope

-r Get Real sub-bottom data

-u Get Raw (uncorrelated) sub-bottom data

-o Path and name of output file

Example: jsf2segy –a Data10.jsf –o Data10.sgy ➔ convert analytic (correlated) Data10.jsf to analytic Data10.sgy

jsf2segy –u Data10.jsf –o Data10.sgy ➔ convert raw (uncorrelated) Data10.jsf to raw Data10.sgy

lstjsf

mc4g11@sarge.noc.soton.ac.uk>lstjsf

lstjsf ... Lists Edgetech JSF formatted files

Usage: lstjsf - options full path to input file name

Options -c Get count of Sub-bottom and Sidescan records

-s List Sidescan Sonar message header

-b List Sub-bottom message header

Example: lstjsf –c Data10.jsf ➔ Count how many records are in the Data10.jsf file

msg80

mc4g11@sarge.noc.soton.ac.uk>msg80

msg80 ... Lists Edgetech JSF formatted files

Usage: msg80 - options full path to input file name

Options -c Get count of Sub-bottom and Sidescan records

-s List Sidescan Sonar message header

-b List Sub-bottom message header

Example: msg80 –s Data10.jsf ➔ List Side Scan Message Header of Data10.jsf file

msg82

mc4g11@sarge.noc.soton.ac.uk>msg82

msg82 ... Lists Edgetech JSF formatted files

Usage: msg82 - options full path to input file name

Options -c Get count of Sub-bottom and Sidescan records

-s List Sidescan Sonar message header

-b List Sub-bottom message header

Example: msg82 –b Data10.jsf ➔ List Message Header of the Data10.jsf file

5) Several notes for the user

The original code has been modified to allow the extraction of the raw data collected by Edgetech 2200-M system. Thus, the actual code can deal both with uncorrelated (raw) and correlated (analytic) data formats and the segy data can be easily imported into any seismic processing software.

Correlation of the raw data with the source sweep

After the data format conversion, the source sweep is correlated with the raw data in promax.

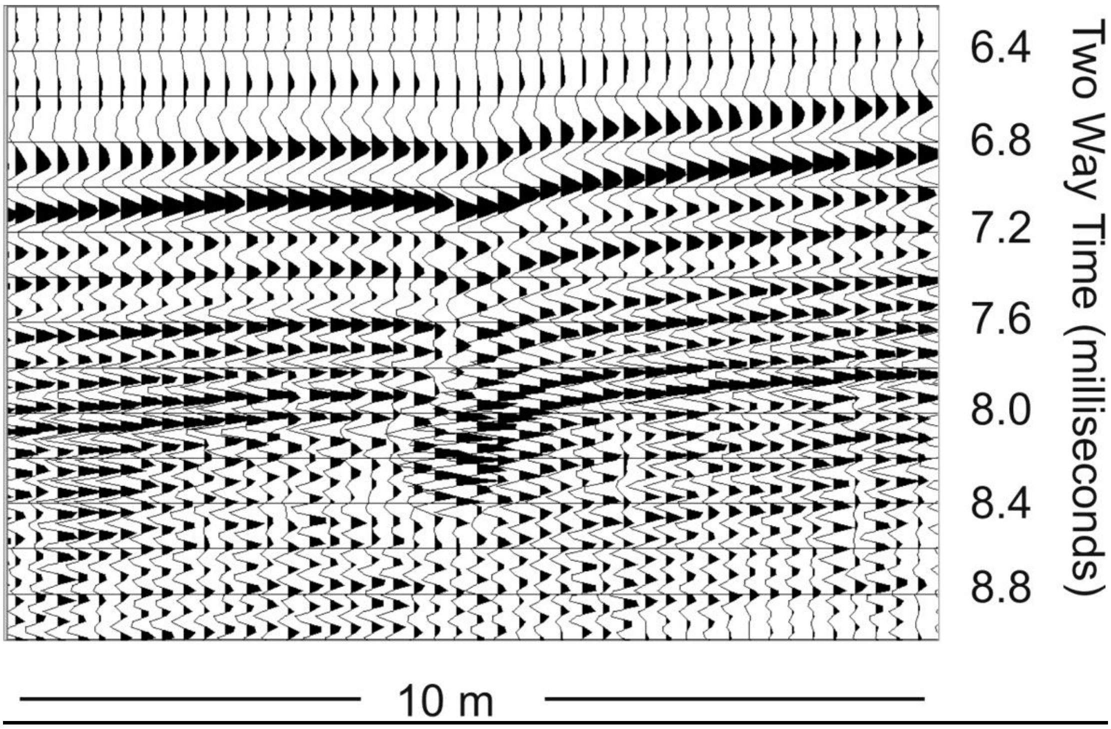
True Amplitude Recovery

A basic processing is applied to the seismic data in order to recover amplitudes, lost by spherical attenuation.

Importing data in petrel

Some of the lines are imported in petrel seismic interpretation software to check their quality.

Example of Chirp data over a suspected seabed fracture with associated bright spot 1.2 – 1.5 m beneath the seabed



Section 3. Autosub6000.

Steve McPhail

Mission Summary

There were a total of 10 successful science missions. 708 km of lines track was surveyed over a period of 141 hours with a combination of: HFSSS (410 kHz) sidescan sonar, Chirp Profiler, a 5 M Pixel digital colour camera stills, pH, Eh, CTD with DO , and light back scatter sensors.

The availability and operating reliability were 100%, and the data return rate from the sensors was also 100% except for a small percentage of the Edgetech files which were unreadable due to some corruption in the data written to disk. These are probably recoverable (Edgetech will be contacted).

Table 3.1 is a general summary of the Autosub6000 missions on JC060.

#	Start and end date & time [GMT]	Mission Duration Hrs	Location	Start Position	Max Depth (m)	Altitude(s) [m]	Distance travelled [km]
59	05-Sep-2012 13:02:08 06-Sep-2012 03:59:30	15.0	Seismic Chimneys	N:58:19.505,E:1:55.600	81	12 and 3.2	72
60	07-Sep-2012 06:58:54 07-Sep-2012 20:54:16	13.9	Middle Area	N:58:32.892,E:2:0.687	87	12 and 3.2	70
61	08-Sep-2012 18:44:04 09-Sep-2012 08:53:24	14.2	Northern Fracture	N:58:36.315,E:2:5.544	80	12 and 3.2	70
62	09-Sep-2012 21:43:28 10-Sep-2012 11:49:12	14.1	Northern Fracture	N:58:35.240,E:2:5.720	88	3.2	71
63	10-Sep-2012 20:56:28 11-Sep-2012 06:44:58	9.8	Middle Area	N:58:32.622,E:2:0.694	83	3.2	49
64	15-Sep-2012 22:38:25 16-Sep-2012 14:49:09	15.0	Northern Fracture	N:58:36.293,E:2:2.137	75	12.0	75
65	17-09-2012 18:08:04	14.6	Sleipner CO2	N:58:24.326,E:1:57.653	70	12.0	73

	18-Sep-2012 07:36:14		plume				
66	20-Sep-2012 08:34:34 20-Sep-2012 21:48:22	14.6	Sleipner CO2 plume	N:58:24.326,E:1:57.653	79	3.0	73
67	21-Sep-2012 18:58:46 22-Sep-2012 09:24:40	14.4	Middle Area	N:58:32.622,E:2:0.694	80	4.0	73
68	22/09/2012 18:53:10 23-Sep-2012 11:06:34	16.2	Connecting all three areas	N:58:34.924,E:1:59.388	72	12 m	83

Navigation Performance

The JC077 missions were interesting for the evaluation of the navigation performance of Autosub6000, as the shallow depth meant that continuous bottom track navigation was possible between the start and the end GPS fixes. In addition, with pipelines intersecting many of the tracks, it was possible to evaluate the navigation drift on a track by track basis.

There were two main issues affecting the accuracy of the navigation, and of merging of the navigation and Edgetech data.

1) Increased variance of velocity measurement at 3 m altitude, compared to missions at 12 m altitude.
2) Lack of Synchronisation between the Edgetech logger and the AUV navigation logger.

Figure 3.1 illustrates the first issue. The standard deviation in north velocities for Mission 64 (blue) at 0.016 m/s are significantly less than those for mission 66 (red) at 0.099 m/s.

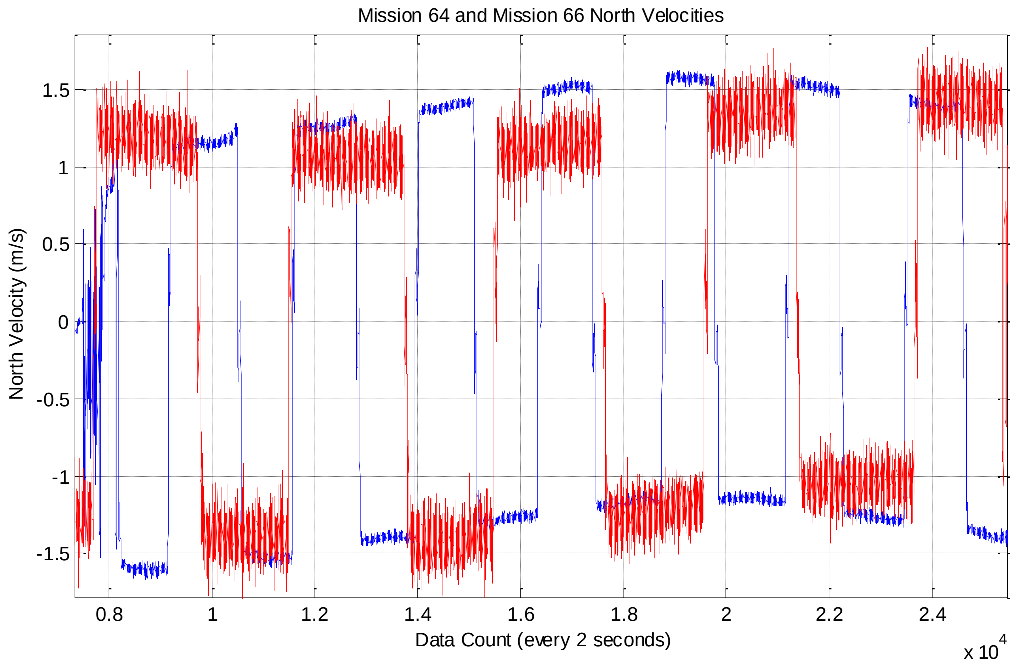


Figure 3.1. Increased velocity measured variance at low altitude. Red trace is for the 3 m altitude mission, the blue for the 12 m altitude mission.

The effect of this variance is enough to produce noticeable offsets on a line by line basis, and explains the larger final GPS position fix jump for the missions run at 3 m altitude compared to the missions run at 12 m altitude. The manufacturers of the ADCP used for navigation (Teledyne RDI) discuss use of a different operating mode for low altitude operation, giving significantly reduced variance. However during the cruise it was considered too risky to change the operating mode of the ADCP, and hence this was not tried.

Table 3.2 is a summary of the average navigation drift as measured by comparing the dead reckoned position with the GPS fix at the end of the mission.

The lack of synchronisation between the Edgetech logger and the AUV logger meant that to match the Edgetech sonar data with the navigation, we first measured, then corrected for, the relative clock drifts in the post processing. However, since the relative drift rates were both quite large (of order 50 to 100 ppm) and variable, then the resulting uncertainty in position due to this cause could be of order 2 m.

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#	Flying Altitude	N drift (m)	E drift (m)	Drift Rate (km/hour)
59	12	4.0	23.1	1.4
60	12	-16.8	39.0	2.9
61	12	-11.4	-29.3	2.3
62	3.2	-20.7	8.9	2.6
63	3.2	NA[1]	NA[1]	NA[1]
64	12	15.9	21.2	2.1
65	12	-27.5	-2.1	2.0
66	3	4.1	-79.6	5.9
67	3	48.7	49.0	4.7
68	12	-13.2	11.6	1.0

Table 3.2 *Summary of Navigation Drift for the 10 missions. For Mission 63 [1], a navigation offset command was sent to the AUV when it was subsurface in order to safely avoid fishing boats. The effect of the offset was that the navigation system rejected the GPS fixes when the AUV surfaced, as it calculated them to be outside of sensible range. Note the worse drifts at the lower altitudes.*

Sonar devices installed on Autosub6000

The system consists of a dual 120 kHz, 410 kHz sidescan system, with a 2 to 15 kHz sub bottom profiler. The one way beam width is reported to be 0.3 degree for the 410 kHz, and 0.8 degree for the 120 kHz. On JC077, only the HF (410 kHz SSS) and SBP was used.

Autosub Sensor Configuration

The sensor suite fitted to Autosub6000 are listed in Table 1. Photographs 1 to 6 show the installation of the CTs, Oxygen, EH, camera and flash, multi beam, side scan and sub bottom profiler. Each CT assembly was mounted on the inside of the nose panel with a 40mm (i.e. short) length of tube plumbing the water outside the vehicle to the temperature sensor (photo 1).

The Edgetech sub bottom profiler (SBP) was mounted in the tail section with the receivers were mounted outside the vehicle on the centre section (Photo 8, 9).

Table 3.3. *Autosub sensor suite for JC0060*

Description	Part No.	Source	Serial No.
CTD Port Temp	90565	Sea Bird	03P5009
CTD Port Cond’	90468	Sea Bird	043499
CTD Stbd Temp	90465	Sea Bird	03P5071
CTD Stbd Cond	90468	Sea Bird	043566

Oxygen sensor	90599.2	Sea Bird	431582
CTD Pump Port	90544	Sea Bird	055125
CTD Pump Port	90544	Sea Bird	055238
CTD Logger	90538.042	Sea Bird	09P52764-0930
EH Sensor		Ko-ichi Nakamura	
PH Sensor		Kiminori Shitashima	
Light Scattering Sensor (LSS)		Sea Point	
300 kHz ADCP		RDI-Teledyne	
Depth sensor	NOC dwg No A5952	Digiquartz Inc.	
Camera		5 M pixel colour (see later section for details).	
Side scan, Sub bottom profiler		Edgetech 2200 system. Only the 410 kHz (HFSSS) and Chirp profiler were used on this cruise.	

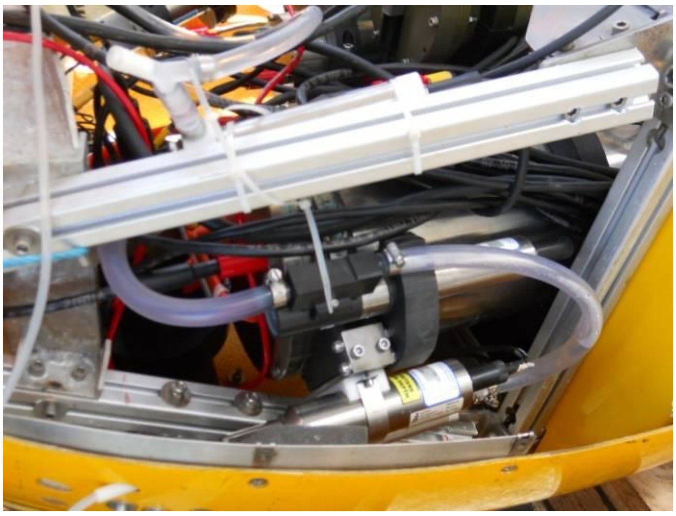

Photo 1. Port CT (mounted below the panel split line) and Oxygen sensor uppermost

Photo 2 EH sensor on starboard side protruding through panel. PH sensors were also mounted in this position.

Photo 3. Edgetech electronics mounted in the tail

Photo 4. Edgetech Side Scan inset into the centre buoyancy blocks just below the winglets

Photo 5. Looking up at the tail section, 'bumble bee' tape covers the aperture cut for the SBP transmitter.

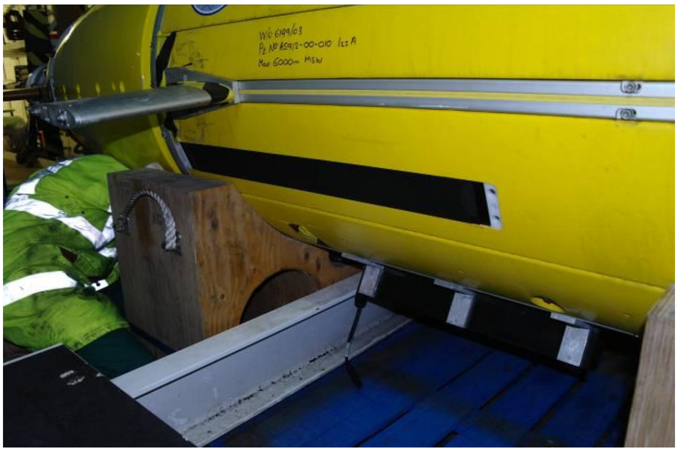

Photo 6. Sub bottom profiler receivers (bottom of photo) mounted outside vehicle

Launch and recovery

The new Lawson Engineering Ltd gantry was mounted on the port side 'ROV position'. The equipment performed well and most launch and recoveries were without drama. As with previous side launch positions, the AUV was set running for 30 seconds away from the ship as soon it hit the water; this was fond in practice to be essential due to the suction effect near the ship. The biggest problem was the lack of visibility for the bridge from this position. Initially the lines were grappled just aft of the gantry position, but visibility being particularly bad for this position, grappling was moved to the port quarter, with more success. The grapple gun achieved only 3 hits, due partly to good throwing arms of the deck seamen. The AUV washing line was extended into the tail and nose sections, much easing grappling.

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Photo7. The Autosub6000 MKII L&R system installed on the aft deck of the RRS James Cook. The red tape (rather comically) showing the position of some top panel damage due to ship collision on the last recovery

Autosub 6000 Data Files and Formats

Autosub6000 Files Handed over for JC077.

Cruise Summary Files and Sensor Calibration Data.

Filename	Description
Cruise Report Autosub JC077.docx	Cruise Report - THIS
JC077 Data Handover Files and Formats.docx	
JC077 Autosub Missions Summary.xlsx	Summary information for all the missions, including start and end times, start positions,
JC077 Cameras Setup and Files.docx	Detailed information on the Camera Setup and file formats.
JC077.con	The calibration file for the CTD.

Files for Each Mission M059 through to M068

Separate large files for the Edgetech and the Camera systems.

Folder/ Filenames	Description
/M0*XX*EdgetechData/DATA0000001X.jsf	Edgetech .jsf files. For Mission 59 these were 10 minute files. For Mission 60, new files were started at the beginnings of lines, with a ten minute timeout. For all subsequent files the time limit was 30 minutes, and new files were produced for each line. For Mission 68, with 20 km long lines there are several files per line.
/MXX_05092012_123052_10441297/ MXX_10441297_xxxxxxxxxxxxxx.raw	Raw format Camera Image data. One every 0.8 seconds of all the missions.

Navigation and Sensor Data Files. In JC077final26thSeptember.zip zip archive. Example for Mission 060:

M060_Mission Info.txt	Some basic Mission Information. Start and end times, survey duration and most common values of water depth, AUV depth and AUV altitude.
M060_PHSensorData.csv	All sensor (except Edgetech or Camera) on a common time base with the AUV post processed navigation data. Comma separated values, with time in excel format. *Format description.*
M060_Sensors.mat	Matlab version of the above file. *Format description.*
_10HzM060.mat	The 10 Hz up-sampled version of the post processed AUV navigation data, with the timebase adjusted to the offset and drift rate of the Edgetech raw clock (the .jsf files). *Format description.*
M060_EdgeTechNav.txt	Text file with the post processed AUV navigation (as above), time corrected to align with the Edgetech data. *Format description.*
M060cam.txt_imageData.csv	File with the post processed navigation data for each of the camera frames taken. *Format description.*
M060ETtimeOffset.m	The time offset and drift rates of the Edgetech logger compared to the AUV navigation logger. Note that this is for information only. The corrections have been already applied to the applicable files.

M060NavPerformance.txt	A measure of how far the dead reckoned navigation had drifted during the submerged portion of the mission. This is for information only, the applicable correction has already been applied to the post processed navigation data.
FiguresM060 (Folder)	A series of figures of the 2 D scatter (longitude, latitude as X, Y, and the signal colour coded). pdfs and Matlab versions. The Matlab versions are more generally useful as the figures can be zoomed, and more usefully the range of the colour scale changed. The figures which are "high passed" are high passed filtered (achieved by subtracting low pass filtered version of data) , in order to remove the low instrument drift , and emphasise the short term changes in the data. Include, also, a time series of all the sensor data. The high passed filter time constant is 30 seconds.

Time Offset Issues between the Edgetech and the Autosub logger clocks

The reference time for all Autosub6000 sensor data is the clock on the Autosub6000 logger. This maybe a few seconds difference from UTC, but this is no practical importance.

Unfortunately, it was not possible to synchronise the clocks on the Edgetech system with the times on the logger, hence there is a time offset and drift between the two.

As a work around for this problems, prior to each mission dive, and post the surfacing of the AUV, a program running on a lab computer measured the relative differences between the Autosub logger and the Edgetech clocks, from which the offset (at the dive time), and the rate of drift was calculated.

This time offset and rate for each dive is stored in a file MXXXtimeOffset.m

For the data which is used for matching of the Edgetech data with the logger navigation data, this offset and rate are applied to the logger data. Hence for the files, e.g. Mission M060 :

M060_EdgeTechNav.txt, and *_10HzM060.mat* This offset has been already applied.

So it should be remembered that for *only* these particular files, the clock has been adjusted to be synchronised with the Edgetech time.

Autosub File Formats

MXXX_PHSensorData.csv:

Format: ASCII Text. Comma Delimited. The Date format is readable directly by excel as date/time. There is a one row header.

For each value recorded for the Kiminori Shitashima pH sensor, there is a set of navigation data.

All the navigation data is based on the post processed navigation (includes the correction applied after the GPS fix at the end of the mission).

Name	Unit	Description
MissionName	#	e.g. M060
Mission Date	Excel Time	
Latitude	Degrees	e.g. 58.123456 Positive is North. Ref geoid is WG84
Longitude	Degrees	e.g. 1.123456 Positive is East.
Depth	m	AUV depth in m. Deeper is more positive.
Altitude	m	AUV Altitude off seabed (measured by ADCP)
PitchDeg	Degrees	AUV Pitch (nose up is positive)
RollDeg	Degrees	AUV Roll (nose down is positive)
HeadingDeg	Degrees	AUV Heading (normal navigation sense – east is 90 degrees)
Ground Speed	$m\ s^{-1}$	Speed relative to see bed.
Eh	see CTD cal	
CTDPres	dBar	
S1	psu	
S2	psu	
T1	Celsius	
T2	Celsius	
DO	See CTD cal	
LSS	See CTD cal	
d1	unknown – refer to Kiminora Shitashima	
t1	“	
d2	“	
t2	“	
d3	“	

MXXX_Sensors.mat

The format is a Matlab variable ‘PH’ with the structure elements identical in meaning to those (above) for the ASCII ‘MXXX_PHSensorData.csv’, with one exception: The time variable ‘PH.eTime’ is the number of seconds since 1/1/1970.

_10HzMXXX.mat

This file was produced to enable AUV navigation data to be inserted into the Edgetech jsf header files.

This Matlab file with up-sampled (from 0.5 Hz to 10 Hz) post processed (for end GPS position) navigation data. The navigation is smoothed with a time constant of 30 seconds with a filter designed to give minimal time lag. The timebase has been adjusted to be as close as possible matching the Edgetech Clock, using the measured offset and drift rate of the Edgetech clock relative to the Autosub Logger clock. The data field are:

usAltitude	m	AUV Altitude off seabed (measured by ADCP)
usDepth	m	AUV depth in m. Deeper is more positive.
usHeading	Degrees	AUV Heading (normal navigation sense – east is 90 degrees)
usEast	Degrees	e.g. 1.123456 Positive is East.

usNorth	Degrees	e.g. 58.123456 Positive is North. Ref geoid is WGS 84
usPitch	Degrees	AUV Pitch (nose up is positive)
usRoll	Degrees	AUV Roll (nose down is positive)
usSpeed	m s^{-1}	Speed relative to see bed.
usTime	seconds	Number of seconds since 1/1/1970. The time increment is 0.1 seconds. The time is offset and drift corrected to match that of the Edgetech time stamp.

MXXX_EdgeTechNav.txt

The file is a fixed field format for importing into the Edgetech HFSSS processing software. The number of white spaces is important for correct parsing.

e.g.:
Mission   Date   Time NorthDeg EastDeg HeadingDeg RollDeg PitchDeg Depth Altitude Speed
M066   120920 082757 58.405140   1.961891   194.758 -16.366 0.451   10.057 74.468 1.044

The fields are self explanatory and defined the same as for the _10HzMXXX.mat.

MXXXcam.txt_imageData.csv

This file gives (post processed) navigation data for each frame taken by the Autosub downward looking camera. For more information see: *'JC077 Cameras Setup and Files.docx'*

FIELD	DESCRIPTION
Time	Time of frame in excel format (days since 1900).
Altitude_m	Altitude of AUV in m. Is set to 'NaN' if no data (> 200 m altitude). The
AUVdepth_m	AUV depth in m. Interpolated for each frame.
WaterDepth_m	The water depth is AUV depth plus AUV altitude. (NaN if no valid altitudes). Is interpolated for each frame.
Latitude_deg	The decimal latitude in degrees. This is post processed navigation, low pass filtered to reduce jitter, and interpolated for each frame.
Longitude_deg	The decimal Longitude in degrees. This is post processed navigation, low pass filtered (with zero delay) to reduced jitter, and interpolated for each frame.
Pitch_deg	AUV pitch (positive is nose up) in degrees. Interpolated for each frame.
Roll_deg	Roll (positive is starboard down). Interpolated for each frame.
Heading_deg	Heading (positive clockwise from north). Interpolated for each frame.
Frame_Filename	The Filename is e.g. *M55_11370385_12987210455670.raw. Mission Number/Serial Number of Camera/timestamp* milliseconds since the start of 1700.The raw is format at 8 bits per pixel.

Section 4. Multibeam
Tim Le Bas

Multibeam bathymetry (EM710)

The shipboard multibeam shallow water system (EM710) was used regularly during the cruise. It collected over 600 files each of about 750Mb for each 30 minutes of data. This was unusually large due to the inclusion of the water column data within the files. For future cruises collecting this water column data, it is recommended that this is to be held on separate files as it slowed the bathymetry processing considerably. Bathymetry data were processed in CARIS HIPS v7.1.1. The data was corrected with a sound velocity provided by a CTD dip. No tidal correction was done but this did not seem to affect the data.

A calibration survey for transducer orientation was conducted just offshore Aberdeen and a value of -4.0 degrees was found for pitch and 0.34 degrees for roll.

The bathymetry values varied between 80m and 111m though a lot of noise was also present and required considerable manual editing to remove outliers. Lines travelling east to west were particularly noisy in comparison to the reverse direction. Lines were spaced at 250m. Some small holes in the survey are due to bad weather or suspension of survey lines to go to sampling stations. Some lines were repeated to improve on the previous poor data. Final data coverage was 246 sq km at a resolution of 5m.

Multibeam backscatter (EM710)

As with the bathymetry system the backscatter data did suffer from poor data quality. Data were converted and transferred to the PRISM (v5) system for processing. Ship track lines were extracted from the stored data and 15 map areas chosen, as the coverage was too large for a single map. Due to the poor signal-to-noise ratio the backscatter mosaic was done at 2.5m whereas it would be hoped to be done at 1m. Survey speed was about 6 knots and pulse repetition was about 0.5 seconds and thus ping spacing was about 1.5m. Repeat surveyed lines were handled separately and mosaiced on top of the original data. The PRISM Processing configuration was:

```
mrgnav -i %1 -o %0 -n navfile.nav -l 0,0
sshead -i %1 -o %0 -a 2.0
filter -i %1 -o %0 -b 1,21 -z -v 130,255
filter -i %1 -o %0 -b 1,301 -h -v 130,255
filter -i %2 -o %0 -b 31,301 -L -v 130,255
wtcombo -i %2 , %1 -o %0 -c 1,1 -a -128
restorehdr -i %1 -h %5
resol -i %2 -o %0 -a -r res
shade -i %1 -o %0 -n 128 -t 1,254
```

Autosub 6000 Edgetech Sidescan

Following each Autosub deployment the jsf data was downloaded from the vehicle and transferred to the PC replay system (Discover 4200 MP 2.03). Data were replayed thus allowing it to be viewed and converted into xtf format. This is a slow and laborious process typically taking over an hour per mission. Some difficulties were encountered when replaying the data and some coverage was lost. A table of the missions and the data files lost is provided. The amplification gains are set by the user according to the sidescan values. These were kept constant for each deployment and were generally set according to their programmed mission altitude:

12m altitude	29dB for Gain and 18dB for TVG over 100m
3m altitude	25dB for Gain and 20dB for TVG over 100m

Data were converted and transferred to the PRISM (v5) system for processing. Navigation for Autosub is provided separately and this was imported from a spreadsheet. The sidescan mosaic was generally done at 0.5m though some smaller specific areas were processed at 0.1m. Survey speed was about 2.8 knots and pulse repetition was about 0.21 seconds and thus ping spacing was about 0.3m. The PRISM Processing configuration was:

```
widealt -i %1 -o %0 -p
mrgnav_inertia -i %1 -o %0 -u 0 -r 0.0,0.0 -n navfile.veh_nav
edge16 -i %1 -o %0 -m
tobslr -i %1 -o %0 -r0.0576 , res #  HF 110m 6 Hz subsamp 5
shade_tobi -i %1 -o %0 -n 1000
foldtobi -i %1 -o %0 -t 3000
filter -i %1 -o %0 -b 1,351 -h -v 1,5000
filter -i %2 -o %0 -b 21,351 -l -v 1,5000
wtcombo -i %2 , %1 -o %0 -c 1,1
restorehdr_tobi -i %1 -h %5
mrgheading -i %2 -o %0 -f -t -n navfile.nav
```

It was found that the Autosub navigation for the 12m altitude sidescan imagery matched the features very well to shipboard multibeam backscatter imagery. Features that crossed from pass to pass such as pipelines or cables matched well with errors being less than 2m. However the 3m altitude imagery deployments showed considerable error in positioning, accumulating error as the mission continued. Some features were measured to be 75m offset from the 12m altitude data. New navigation files were provided and these occasionally improved feature matching.

The processed mosaics were then transferred to the GIS along with a navigation overlay with acquisition times. It was also noted that when Autosub turned from line to line about 8 seconds of data (40 pings) were lost. As these were at the end of the lines it was not considered problematic.

Full instructions for processing are included in Appendix 1.

Section 5. HyBIS operations during JC77

Veit Huhnerbach

The HyBIS vehicle

HyBIS is a simple, low-cost, multi-purpose, survey and sampling robotic underwater vehicle (RUV) with a depth capability of 6000m (Fig 5.1). It was designed and built in the UK by Hydro-Lek Ltd. in collaboration with the National Oceanography Centre, Southampton (NOC), back in 2008. Since then, the vehicle has had 3 successful trials cruises and completed 9 scientific expeditions, from the Arctic to the Tropics.

The vehicle has a modular design that make its very versatile, with the top module being a command and power system that comprises power management, cameras, lights, hydraulics, thrusters and telemetry. Telemetry is via a single-mode fibre optic link and provides 3 channels of real-time standard-definition colour video plus vehicle attitude data. Power is supplied through a single-phase 1500V ac, 8kVA umbilical and converted to 3-phase 120V on the vehicle by two silicon motor controllers, 240V ac for the lights, and 24 to 12V dc for onboard instruments.

The easily changeable lower modules available at the moment include a clam-shell sampling grab, a 5-function manipulator-arm and tool sled, a winch with 600m rope for instrument recovery and an ocean bottom seismometer deployment module. The sampling module used during JC77 during the video surveys comprised a 0.5 cubic metre clam-shell grab with a pay-load capacity of 750kg and closure force of 4 tonnes. 5 sediment samples were taken during the voyage 77 of RRS James Cook.

Unlike a conventional ROV, HyBIS does not have any floatation or buoyancy, it is rather suspended by its umbilical cable directly from the ship which makes it slightly susceptible to ship roll and heave motion, especially in the shallow water depths in this working area. On the positive side, the advantage of direct suspension is that HyBIS can recover or deploy a payload of up to 750kg.

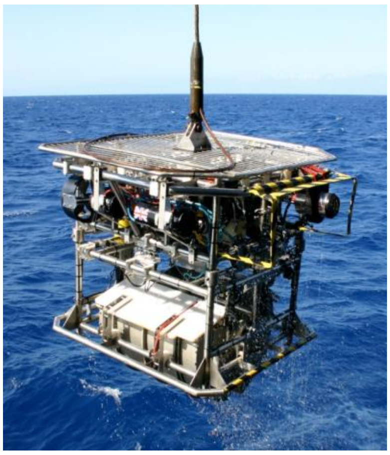

Figure 5.1 Hybis vehicle

Laboratory control unit setup

The top-side control centre (Figure 5.2) was established in the main science lab, on starboard side, right next to the HV cage and the junction boxes for fibre-optics and power. The vehicle's primary control box was supplemented with additional monitors and a relay of the USBL navigation screen. A dedicated GPS aerial was mounted on an out-rigger over the starboard side and provided a continuously recorded GPS string to the Garmin GPS navigation system in the control box. Unfortunately, the GPS signal was lost on several occasions due to the location of the GPS antenna which was limited by the length of its cable. Winch controls were established adjacent to the vehicle pilot's position, allowing synchronisation between winch operator and pilot.

Video was recorded digitally as DV and AVI formats on 2Tb hard-discs. Two cameras (forward and downward SD) were recorded continuously in standard definition. The forward looking camera with vehicle attitude data overlain was also recorded on DVDs of about one hour length. Full HD video (1080i, PAL, 30fps, AVCHD format) was not used. Back-ups of all dive data and videos were then made on regular intervals. All GPS navigation data were recorded on the top-side command unit and copied to a USB portable drive. Time codes were all set and synchronised to GMT.

Acoustic navigation was provided using the vessel's Sonardyne USBL tracking system with a mini-transponder beacon on the HyBIS vehicle. Tracking was generally good although transponder battery conditions provide a limited maximum dive time of about 6-8 hours until recharge becomes necessary. The computing representative onboard recorded all available USBL navigation data.

Figure 5.2. left to right, top to bottom: Lab setup showing video screen and logging system arrangements for HyBIS and its main control box.

High-voltage power setup

Prior to the HyBIS HV transformer being installed in the main lab, a lockable enclosure (Fig xxx) needed to be installed in order to comply with UK high-voltage regulations. HV safe working procedures were put in place, and kindly overseen by the HV responsible person Ian Pheasant (BGS), which meant that HyBIS was not to be switched on prior to deployment and recovery. All procedures were communicated to and agreed with the crew. HV working permits were issued and signed off for each deployment. In addition, an area of the mid-ship deck, just outside the CTD wet lab was cordoned off during all HV operation.
Before recovery of the vehicle, tests were made to ensure that no residual current was left in the deep-tow cable, allowing safe handling onto the deck. In addition, an earthing rod was attached as additional safety.

Figure 5.3. HV cage onboard RRS James Cook.

Dive narrative and vehicle performance summary

15th September 2012, HyBIS Dive #124
Sleipner Area (58° 35.760N, 002° 05.343E), water depth ~92m
Aim: Inspect seabed observatory (deployed from RV Maria S. Merian) and carry out short seabed video survey, possibly a grab sample.
A grab sample was taken successfully at 2109hrs.

16th September 2012, HyBIS Dive #125
Sleipner Area (58° 35.784N, 002° 01.800E), water depth ~95m
Aim: Video survey in the a drill well area and collection of a grab sample
A grab sample was taken successfully on a bacterial mat at 1938hrs. EH-sensor was attached to the front of the vehicle.

16th September 2012, HyBIS Dive #126
Sleipner Area (58° 35.742N, 002° 01.698E), water depth ~95m
Aim: Video survey in the a drill well area and collection of a grab sample
Dive was abandoned at power up in 50m depth due to a camera malfunction.

16th September 2012, HyBIS Dive #127
Sleipner Area (58° 35.742N, 002° 01.699E), water depth ~95m
Aim: Video survey in the a drill well area and collection of a grab sample
A grab sample was taken successfully on a bacterial mat at 2142hrs. EH-sensor was attached to the front of the vehicle.

17th September 2012, HyBIS Dive #128

Sleipner Area (58° 32.625N, 002° 02.808E), water depth ~90m
Aim: Video survey of the seabed
EH-sensor was attached to the front of the vehicle.

17th September 2012, HyBIS Dive #129
Sleipner Area (58° 32.316N, 002° 00.936E), water depth ~90m
Aim: Video survey of the seabed
EH-sensor was attached to the front of the vehicle.

18th September 2012, HyBIS Dive #130
Sleipner Area (58° 22.872N, 001° 57.432E), water depth ~83m
Aim: Video survey of the seabed
EH-sensor was attached to the front of the vehicle.

18th September 2012, HyBIS Dive #131
Sleipner Area (58° 22.542N, 001° 57.570E), water depth ~83m
Aim: Video survey of the seabed and collection of a grab sample
A grab sample was taken successfully on a high-backscatter mound feature at 0032hrs (19^{th} September). EH-sensor was attached to the front of the vehicle.

19th September 2012, HyBIS Dive #132
Sleipner Area (58° 32.244N, 002° 00.913E), water depth ~89m
Aim: Video survey of the seabed
EH-sensor was attached to the front of the vehicle. Dive was cut short due to the USBL battery being discharged. No GPS on the vehicle overlay data at the beginning of the dive.

19th September 2012, HyBIS Dive #133
Sleipner Area (58° 32.200N, 002° 00.915E), water depth ~89m
Aim: Video survey of the seabed
EH-sensor was attached to the front of the vehicle.

21th September 2012, HyBIS Dive #134
Sleipner Area (58° 35.762N, 002° 05.268E), water depth ~94m
Aim: Video survey of the seabed along Northern Fracture and collection of a grab sample
A grab sample was successfully taken on bacterial mats at 0221hrs. EH-sensor was attached to the front of the vehicle.

With almost 13 hours of seabed video survey time and 5 grab samples, HyBIS was an integral part of the science program for the second part of the cruise. The video surveys helped ground-truthing the extensive acoustic surveys of the AUV and ship-borne equipment, and the grab samples brought sediment and biological samples onboard.
The integration of the Eh-sensor (Fig 5.4) also allowed continuous measurements during the HyBIS dives. Its results showed PH-changes over limited small scale features that indicated possible venting activity.

Figure 5.4. EH-sensor (left side) attached to the HyBIS vehicle

HyBIS operations were stopped on the evening of September 21st due to damage of the fibre-optic cable during the changeover from Megacoring to HyBIS. Re-termination took until midnight of that day. The, almost daily, changeover of the cables and consequent terminating and disconnecting of the vehicle was not ideal, but unavoidable to allow continuous science operation.
Upcoming bad weather conditions led to the cancellation of all further HyBIS operations planned for the remainder of the cruise.

Section 6. Water column and sediment (bio)geochemistry

Anna Lichtschlag, Douglas Connelly, Mark Hopwood, Mario Esposito, Belinda Alker,

Background

The aim of the (bio)geochemical water column and sediment sampling and analyses during this cruise was to: search for tracers of leakage of formation fluids or precursors from the spreading sub seafloor CO_2 plume at the Sleipner CCS site, to identify potential mobilization of toxic metals by CO_2, and to characterize the environment in the vicinity of the Sleipner storage site.

The main target areas for sediment sampling were the newly discovered ”Middle Area” Station 2, about 18 km north of Sleipner, the “Northern Fracture” area about 25 km North of Sleipner (Station 5) and the ”Area above the spreading CO_2 plume at Sleipner” (Station 7). In order to monitor the distribution of solutes and solids at these potential CO_2 seepage sites, long sediment cores were retrieved with the vibrocoring technique (VC, maximal length 3.79 m, Fig. 6.a). As occasionally the upper sediment layer is lost during vibrocoring, sediment sampling was complemented by retrieving undisturbed sediment surface samples using a Megacorer (MC, maximal length 15 cm, Figx.1b). Altogether 12 VC and 5 MC were sampled for geochemical analyses and for each core a duplicate core was taken to be archived and used for later mineral analyses Table x.1/Table x.2.

Localisation of possible seepage and determination of background concentration was performed by CTD measurements and water sampling. Here, in addition to the above mentioned target sites, the “Southern Chimneys” (Station 1), the “Bubble Site Well Number 15/9-11” (Station 2), the “Well Head 15/9-16” (Station 4), and the “Area between Northern Fracture and Middle Area” (Station 6) were sampled. Sea water samples were collected from a total of 63 CTDs across the 7 areas of interest. Table X.

Figure 6.1 a) Vibrocore sampling b) CTD sampling and c) a megacore sample

Event	Area	Label	Latitude(N)	Longitude (E)	Water depth (m)	Purpose	Length of Core (m)
71	5	JC077-VC01	58.5947167	2.08823333	94	Geochem.	2.92
72	5	JC077-VC02	58.5947167	2.08823333	94	Archive	2.88
72	5	JC077-VC03	58.5956167	2.08898333	94	Geochem	2.95
92	5	JC077-VC04	58.5959833	2.08895	94	Geochem.	3.30
93	5	JC077-VC05	58.5959833	2.08895	93	Archive	2.81
93	5	JC077-VC06	58 35,762	2 04.965	93	Geophysics	3.49
114	5	JC077-VC07	58.5960333	2.08021667	94	Archive	3.37
115	5	JC077-VC08	58.5960333	2.08021667	94	Geochem.	3.50
141	5	JC077-VC09	58.5957667	2.08021667	93	Archive	3.35
142	5	JC077-VC10	58.5957667	2.08021667	93	Geochem.	3.79
183	5	JC077-VC11	58.59325	2.0676	92	Archive	3.15
184	5	JC077-VC12	58.59325	2.0676	92	Geochem.	2.60
201	5	JC077-VC13	58.59305	2.06816667	93	Archive	2.38
202	5	JC077-VC14	58.59305	2.06816667	93	Geochem.	2.46
220	7	JC077-VC15	58.3745167	1.95128333	83	Geochem.	2.35
248	2	JC077-VC16	58.5373	2.01418333	89	Geochem.	2.82
249	2	JC077-VC17	58.5373	2.01418333	89	Archive	1.92
250	7	JC077-VC18	58.3749167	1.95095	81	Archive	2.70
286	7	JC077-VC19	58.3837833	1.95385	84	Archive	1.60
287	7	JC077-VC20	58.3837833	1.95385	84	Geochem.	3.20
316	5	JC077-VC21	58.5957833	2.02843333	96	Archive	1.86
317	5	JC077-VC22	58.5957833	2.02843333	96	Archive	Not collected
318	5	JC077-	58.5957833	2.02843333	96	Geochem.	1.94

		VC23					
340	2	JC077-VC24	58.5389667	2.01421667	89	Geochem.	2.98
341	2	JC077-VC25	58.5389667	2.01421667	89	Archive	1.54
342	5	JC077-VC26	58.5958167	2.08271667	93	Geophysics	3.1
377	5	JC077-VC27	58.5960167	2.08248333	93	Archive	1.63
378	5	JC077-VC28	58.5960167	2.08248333	93	Geochem.	3.0

Table 6.1 Vibrocore sample information

Event	Area	Label	Latitude(N)	Longitude (E)	Water depth (m)
217	5	JC077-MC1	58.5908	2.02373	95
247	2	JC077-MC03	58.5373	2.01418	89
288	7	JC077-MC04	58.3837	1.95377	84
296	5	JC077-MC12	58.5959	2.08878	93
297	5	JC077-MC13	58.5929	2.06677	93
319	5	JC077-MC18	58.5958	2.0284	95
356	5	JC077-MC31	58.596	2.08248	92

Table 6.2 Details of Megacores, From each station one core was used for geochemical measurements and a 2nd one was archived.

No.	Lat °N	Long °E	Bottles fired	Depths (m)
1	58° 31.08	1° 57.19	1-5	77, 5
2	58° 35.683	2° 05.294	1-15	76, 74, 70, 66, 60
3	58° 35.762	2° 04.965	1-15	84, 8, 75, 70, 5
4	58° 35.737	2° 05.339	1-15	80, 78, 74, 67, 8
5	58° 35.745	2° 04.816	1-15	88, 85, 82, 78, 5
6	58° 35.618	2° 04.036	1-15	84, 82, 79, 73, 7
7	58° 35.387	2° 02.925	1-15	88, 86, 84, 79, 7
8	58° 35.624	2° 03.986	1-15	85, 83, 80, 75, 6
9	58° 35.743	2° 04.814	1-15	87, 84, 81, 77, 5
10	58° 35.592	2° 04.128	1-15	87, 84, 81, 77, 5
11	58° 35.606	2° 04.096	1-15	89, 87, 85, 79, 5
12	58° 22.403	01° 56.792	1-15	75, 73, 70, 65, 5
13	58° 22.471	01° 57.077	1-15	77, 75, 73, 67, 5
14	58° 22.575	01° 57.404	1-15	77, 75, 73, 67, 5
15	58° 23.027	01° 56.879	1-15	76, 72, 70, 66, 5
16	58° 23.027	01° 57.231	1-15	74, 72, 70, 64, 4
17	58° 23.029	01° 57.635	1-15	75, 73, 71, 65, 4
18	58° 23.846	01° 56.996	1-15	77, 75, 73, 67, 5
19	58° 23.920	01° 57.230	1-15	74, 72, 70, 64, 4

20	58° 35.786	02° 01.799	1-15	88, 86, 84, 78, 5
21	58° 32.317	02° 00.936	1-15	84, 82, 80, 74, 5
22	58° 32.321	02° 02.132	1-15	83, 81, 79, 73, 5
23	58°35.747	2° 01.706	1-20	90, 88, 81, 85, 5
24	58°32.338	2° 00.853	1-15	85, 83, 80, 75, 5
25	58° 32.2912	2° 0.74898	1-6	85, 83, 5
26	58° 32.292	2° 0.852	1-6	85, 83, 5
27	58° 32.293	2° 0.954	1-6	85, 83, 5
28	58° 32.262	2° 0.806	1-6	85, 83, 5
29	58° 32.262	2° 0.806	1-6	85, 83, 5
30	58° 32.266	2° 0.903	1-6	85, 83, 5
31	58° 32.237	2° 0.756	1-6	84, 82, 6
32	58° 32.239	2° 0.807	1-5, 7	82, 80, 6
33	58° 32.239	2° 0.857	1-5, 7	83, 81, 6
34	58° 32.238	2° 0.911	1-5, 7	82, 80, 5
35	58° 32.239	2° 0.958	1-5, 7	84, 82, 6
36	58° 32.210	2° 0.803	1-5, 7	85, 83, 6
37	58° 32.210	2° 0.853	1-5, 7	85, 83, 6
38	58° 32.211	2° 0.907	1-5, 7	84, 83, 6
39	58° 32.211	2° 0.907	1-5, 7	86, 84, 5
40	58° 32.237	2° 0.546	1-7	85, 83, 5
41	58° 32.183	2° 0.751	1-7	86, 84, 5
42	58° 32.074	2° 0.857	1-6	86, 84, 5
43	58° 32.184	2° 0.855	1-6	85, 83, 5
44	58° 32.184	2° 0.957	1-6	86, 84, 5
45	58° 32.240	2° 01.162	1-6	86, 84, 5
46	58° 31.961	2° 01.173	1-6	84, 82, 5
47	58° 31.959	2° 00.962	1-6	85, 83, 5
48	58° 31.960	2° 00.861	1-6	85, 83, 5
49	58° 31.960	2° 00.753	1-6	85, 83, 5
50	58° 32.186	2° 01.161	1-6	85, 83, 5
51	58° 32.359	2° 01.153	1-6	86, 84, 5
52	58° 32.187	1° 54.669	1-10	94, 92, 83, 60, 5
53	58° 33.322	2° 00.797	1-10	87, 85, 77, 60, 5
54	58° 34.392	2° 00.789	1-10	90, 88, 80, 60, 5
55	58° 31.133	2° 00.299	1-10	84, 82, 74, 60, 5
56	58° 30.062	1° 59.941	1-10	83, 81, 73, 60, 5
57	58° 32.301	2° 06.955	1-14	87, 85, 77, 60, 5
58	58° 28.999	1° 59.417	1-11	82, 80, 72, 60, 5
59	58° 27.930	1° 59.935	1-10	82, 80, 72, 60, 5
60	58° 26.840	1°58.442	1-10	80, 78, 60, 70, 5
61	58° 25.760	1° 57.949	1-10	81, 79, 72, 60, 5
62	58° 24.664	1° 57.472	1-10	81, 79, 72, 60, 5
63	58° 22.751	1° 48.617	1-10	91, 89, 81, 60, 5

Table 6.3. Locations of CTD samples taken, depths and bottles sampled.

Sampling and Methods

Water column sampling

Typically five water depths were sampled; 4 bottom water samples at 2 m intervals from the seafloor and one surface water (5 m depth). Water samples were retained for dissolved trace metal, DIC, nutrient, carbon isotopic, oxygen, total alkalinity, CO_2, CH_4 and ammonium analyses.

Samples for CO_2 and CH_4 analysis were the first to be collected from each CTD in 500 ml blood bags using silicon tubing. Seawater was carefully collected to avoid contact with the atmosphere and the formation of bubbles within the blood bags. 60 ml of nitrogen headspace was then introduced to all blood bags and the bags were then allowed to equilibrate at 24°C for at least 2 hours. Concentrations were determined by gas chromatography using a headspace equilibration method with a reported accuracy and precision of <1%. For this 20 ml of headspace gas was injected through a short desiccating column into a GC-FID. Methane and carbon dioxide headspace concentrations were determined from the area of peaks consistently produced at retention times of 1.68 (CH_4) and 4.76 (CO_2) minutes respectively. Peak heights were calibrated daily using 3 standards (a blank of pure N_2, 20 ppm CH_4 and 10 ppm CO_2 plus CH_4 500 ppm CO_2) and an atmospheric measurement. Every 10 samples the 10 ppm CH_4 and 500 ppm CO_2 was re-run to check for instrument drift.

Samples for dissolved oxygen concentration measurements were collected in 100 ml glass bottles immediately after sampling of CO_2/CH_4. 1 ml $MnCl_2$ and 1 ml NaOH/NaI was added on deck and the solutions shaken vigorously until well mixed. Samples were re-shaken 20 minutes later and allowed to settle for >8 hours. Dissolved oxygen was then determined by the Winkler titration (*Winkler 1888*, detection limit 1 µmol O_2 L^{-1}).

Seawater samples were collected for DIC and methane isotopic analysis. DIC samples were collected in 40 ml supra seal screw cap vials and methane in 100 ml glass bottles with a supra seal crimped top. Both samples were collected using silicone tubing with care to avoid the formation of bubbles. To minimise contact with the atmosphere at least twice the volume of the containers was allowed to overflow. Once sealed 10 µL HgCl was added though the supra seal and the samples were refrigerated at 4°C.

Water samples were also retained for nutrient, ammonium, alkalinity and trace metal analysis. Water for nutrient analysis was collected in 30 mL plastic vials and frozen at -20°C. Ammonium samples were collected in 20 mL screw cap plastic vials and then analysed according to the method of *Grasshoff et al. 1999* with indophenol blue using UV/Vis spectroscopy. Alkalinity samples were collected in 30 mL plastic vials and measured via titration with HCl using a mixture of methyl red and methylene blue as indicator and calibrating against the IAPSO seawater standard.

Samples for trace metal analysis were collected directly from Niskin bottle taps into nitric acid cleaned 500 ml plastic bottles which were three times rinsed with the sea water being collected. Samples were then filtered at 0.2 µm within 1 hour of collection. 250 mL of filtrate was stored in a trace metal clean plastic bottle and acidified by the addition of 250 µL ultrapure concentrated nitric acid.

For microbial analysis 10L of sea water was collected in plastic water canisters which were rinsed with MQ three times before use. The water was then filtered using a periclastic pump through filter paper and a column. The filter paper and column were then frozen at -80°C within 2 hours of collection.

Sediment sampling

Immediately after retrieval, vibrocores (VCs) were sectioned in 0.5 m intervals, capped and transported into a CT room cooled to 7°C. Here, holes for sub-sampling were carefully drilled into the plastic VC liner (larger holes for solid phase sub-sampling, smaller ones for pore water extraction), taped to limit oxygen contamination, and the sections were transferred into a glove box filled with nitrogen for sub-sampling sediments and pore water under an oxygen-free atmosphere.

Inside the glove box solid phase samples were taken through the predrilled holes in the core liners. Sampling intervals ranged between 5 and 25 cm, with a higher resolution towards the sediment surface. Subsamples were taken for porosity analyses, stored refrigerated, and CNS analyses, frozen at -20 °C. For methane concentration analyses 3 mL sediment was taken with cut-off syringes and transferred in headspace vials containing 5 mL 1M NaOH. Methane concentration was measured on board on 10 mL of the headspace with a Gas Chromatograph as described above. In addition, from selected cores and depth from Northern Fracture, samples for RNA later were taken for University of Bergen and 2-3 cm^3 of sediment was transferred in the RNA later chemicals and frozen at -20 °C.

Pore water was extracted from muddy sediments directly with Rhizons (Rhizon CSS: length 5 cm, pore diametre 0.2 µm; Rhizosphere Research Products, Wageningen, Netherlands) inserted though pre-drilled holes in the VC liners and connected to a syringe on which a small under pressure was applied. For the rather dry sandy sediments, subsamples were taken with plastic syringes through the larger holes in the VC liners, transferred into centrifuge vials and centrifuged at for 6-10 minutes at 10.000 rpm. Afterwards, pore water was extracted inside the glove bag with Rhizons inserted into the vials prior to centrifugation.

Aliquots of pore water were taken for DIC analyses (5 mL) and δ 13C analyses (2mL) and poisoned with mercury chloride (5 µL) to prevent further microbial turnover. In addition, 2.5 mL of the pore fluid were acidified (6 µL of conc. suprapure HNO_3) for analyses of kations with ICP-MS/ICP-OES.

2-3 mL of the pore water were sub-sampled in a glove bag for H_2S analyses (250 µL pore water fixed in 100 µL ZnAc), ion chromatography (sulphate, chloride analyses, fixed in ZnAC when samples were sulfidic), silicate (UV/Vis spectroscopy) and stored at 4 °C. In addition, total alkalinity and ammonium were measured on board immediately as described above. Remaining pore water was frozen at -20 °C for nutrient analyses.

MC samples were treated and sampled similarly as the VC samples, after extrusion of the sediment inside the glove box in sampling intervals of 2 cm.

Five MCs from areas 2 and 5 with well preserved surface sediment and retained water above the cores were selected for detailed oxygen and iron analysis. Cores were moved to the CT lab and handled at 7 °C within 10 minutes of landing on deck. Push cores were collected immediately before oxygen/pore water analysis using pre drilled core tubing to minimize core handling time and the opportunity for the cores to equilibrate with the atmosphere. Trials of this technique on estuarine sediment collected in Southampton and processed similarly have shown that these precautions are adequate to prevent the oxidation of any FeII rich pore water present within the cores.

Oxygen penetration was determined by use of OX100 probe in the CT lab. Pore water was extracted from cores at 2 cm intervals under N_2. The cores were then extruded and frozen in 2 cm deep sections for solid phase extractions.

A subsample of the pore water collected was added to a ferrozine solution under an N_2 atmosphere within 2 minutes of collection to allow determination of dissolved FeII *(Stookey, 1970)*. Filtration of pore water was not necessary as the Rhizons used to extract water effectively filter the collected water at around 0.2 µm.

Once FeII had been determined spectrochemically at 562 nm, Fe_{Tot} (aq) was determined by the addition of ascorbic acid.

Preliminary Results

Water column sampling

Alkalinity, ammonium and oxygen levels were relatively consistent across the entire CTD dataset showing vertical profiles typical for the North Sea (Fig.6.2). Background CO_2 and CH_4 levels were found to be comparable to those determined on a previous cruise in the same area.

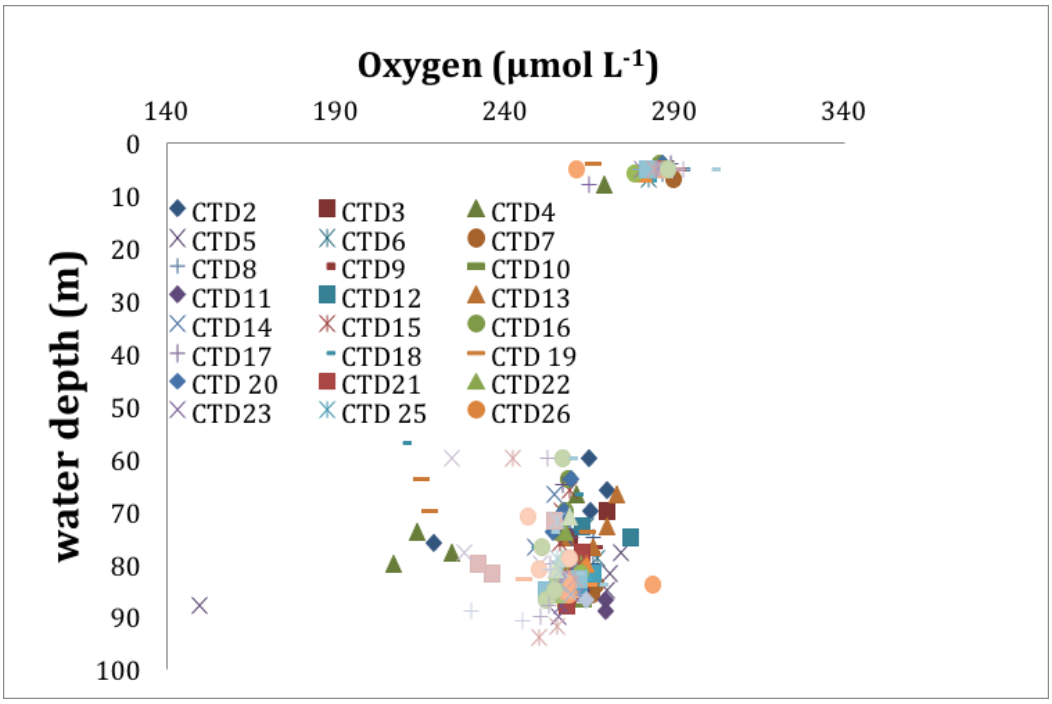

Figure 6.2. Summary of part of the CTD data from JC077

Elevated methane levels correlated well with areas of substantial bubble streams which were observed on the multisounder and using Hybis. Filtered sea water was collected for microbial analysis at sites of elevated CH_4.

CO_2 elevated (>30%) above background levels was measured in multiple bottom water CTD samples at two separate locations. Both locations had been identified as potential sites of elevated CO_2 using an EH sensor on AutoSub and EH/pH sensors mounted on the CTD frame.

Sediment sampling

Sediments in general consisted of sand in the Sleipner and Middle Areas. A shell layer was always found in the upper 30 cm of the vibrocores. Sediments appeared to be uniform in the sampled horizons (mostly upper 3 m). Only in the Northern Fracture area, sediments were finer and had a darker colour, apparently due to iron sulfides precipitated from sulphide production in the sediments. Depth profiles of total alkalinity varied between the sampling sites (preliminary results are shown in Fig. 6.3, and high alkalinity was most likely coupled to sulphate reduction in the sediment (preliminary indication done by sulfidic smell of sediments). Abundance of sulphide in the sediment most likely is correlated to abundance of methane (to be verified after sulphide analyses in the home laboratory), however this was only detected in the Northern Fracture area. Ammonium concentration varied strongly between the sampling sites between 50 and 500 µmol L^{-1}. Oxygen penetration depth varied between 2 and 20 mm. Further results have to await analysis of samples in the home laboratory.

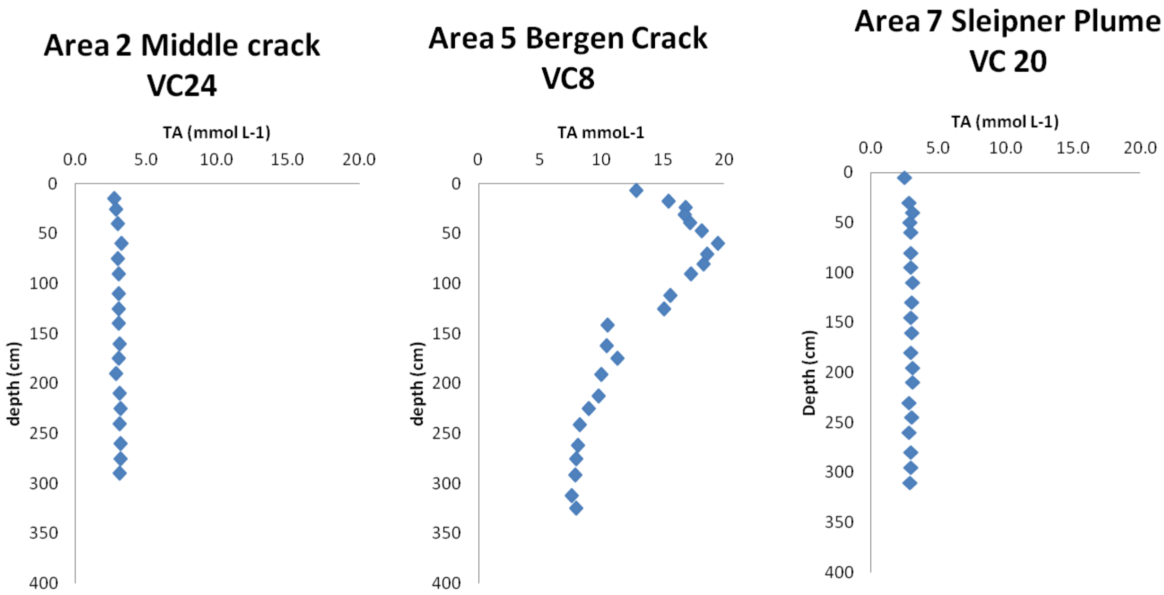

Figure 6.3 Total alkalinity concentrations measured on vibrocores in 3 different areas.

References

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Section 7. BGS Vibrocore operations

David Wallis, Iain Pheasant and Connor Richardson

Equipment Description

The BGS vibrocorer is a steel construction weighing approximately 5tonnes and standing some 8metres tall. It consists of three legs supporting 3 central tubes in a triangular planform. In the middle of the three tubes is a 100mm diameter, 6metre long steel core barrel with a 1tonne weight on top. The 1 tonne weight encloses a vibrate motor within a pressure housing. Within the core barrel is a polycarbonate liner tube fitted with an ‘industry standard’ non-return core-catcher at its base. An electrically driven hydraulic pump allows a Staffa motor winch to retract the core barrel from the seabed back within the frame before vessel base winch recovery to deck.

In operation the sequence is as follows. The vessel stern is located at the desired location and this position is maintained by DP. Once the officers and crew are satisfied that the DP is stable and the vessel is sitting correctly with regard to the swell and sea state, then the vibrocorer is deployed from the stern on a vessel provided hoist warp and lowered to the seabed. An electrical umbilical is secured to the hoist warp during deployment using wide electrical tape every 5metres. Once the vibrocorer is on the seabed, the vibrate motor is switched on and the progress into the seabed is monitored by an acoustic penetrometer with the penetration being displayed graphically and recorded digitally.

Once it becomes apparent that no further penetration is being achieved (a flat line on the graph for ~ 3 minutes) then the vibrate motor is switched off and the retract mechanism started. As mentioned above, this returns the core barrel and core to within the frame, leaving nothing stuck into the seabed. The frame is then recovered to deck for removal of the core from within the core barrel.
When the frame is on the vessel it sits on its side with the feet projecting through the A frame and being supported at the stern by two short (~ 1metre) pivot recovery chains. The top of the frame is secured to deck by another short chain. Deployment and recovery involves rotating the frame to vertical before lowering to seabed and a similar rotation from vertical to horizontal on return.
Further, during transits between sites the hoist warp is disconnected from the top of the vibrocorer and two further securing chains lashed around the support tubes to add deck security.

Observations and Comments

This was the first sea trials of the newly rebuilt BGS 6 metre vibrocorer which included some small innovations while trying to retain the original design success. As the original had been built to Imperial measurements some 30 years ago, the steel sizes were no longer available. The innovations were some improvement to the leg design and a cable termination which was now identical to that of BGS new drill RD2.

The vibrocorer behaved exactly as the previous design, recovering core successfully to depths of 3 metres below the seabed. The use of a ship's hoist warp and dedicated 'soft tow' electrical umbilical proved successful with the umbilical only suffering crush damage requiring repair once.

The TIF images showing the rate of penetration into the seabed indicate that the recovery was limited by the core barrel being stopped when it reached an impenetrable layer such as hard rock or (more likely) till with large cobbles or stones. The images indicate a stiffening of the sediment at around 1 metre penetration as the rate of progress slows.

For a full list of vibrocore samples and locations see Table 6.1.

Section 8. In-situ observation of pH, pCO_2 and ORP by sensor

Kiminori Shitashima

Objectives

In order to detect and monitor the CO_2 leakage form the Sleipner site, in-situ sensor observation of pH, pCO_2 and ORP (Oxidation-Reduction Potential) is conducted by using an AUV (Autosub 6000), a CTD and the Hybis vehicle installed with the sensor.

Methods

The in-situ pH sensor uses an Ion Sensitive Field Effect Transistor (ISFET) as a pH electrode, and the Chloride ion selective electrode (Cl-ISE) as a reference electrode. An ISFET is a semiconductor made of p-type Si coated with SiO_2 and Si_3N_4 as the gate insulator surface that is the ion sensing layer in aqueous phase. The Cl-ISE is a pellet made of several chloride materials and, in an aqueous solution, responds to the chloride ion, which is a major element in seawater. The electric potential of the Cl-ISE shows high stability in the seawater because it has no inner electrolyte solution part in the assembly. The in-situ pH sensor has a quick response (within a few seconds), high accuracy (±0.003pH) and pressure-resistant performance. The pH sensor was then applied as a basis to develop the pCO_2 sensor for in-situ pCO_2 measurement in seawater. Both the ISFET-pH electrode and the Cl-ISE of the pH sensor are sealed in a unit with a gas permeable membrane whose inside is filled with inner electrolyte solution with 1.5 % of NaCl. The pH sensor can measure changes in pCO_2 from changes in the pH of the inner solution, which is caused by CO_2 gas permeating through the membrane. An amorphous Teflon membrane (Teflon AF™) manufactured by DuPont was used as the gas permeable membrane. The in-situ response time of the pCO_2 sensor was less than 60 seconds. The ORP sensor employs platinum wire as a working electrode and the Cl-ISE as a reference electrode, and measures potential difference between both electrodes.

Before and after use, the pH sensor was calibrated using two different standard buffer solutions, AMP (pH: 6.7866) and TRIS (pH: 8.0893) described by Dickson and Goyet, for the correction of electrical drift of pH data. Since the calibration of in-situ pCO_2 measurements was not conducted in our field application reported here, only raw data (arbitrary unit) from the pCO_2 sensor output were obtained. Raw data showing small digit readings indicates pH depression of the inner solution, which reflects an increase in partial pressure of CO_2 in seawater.

The in-situ pH/pCO_2/ORP sensors were installed to the AUV (Fig. 1), CTD-CMS (Fig. 2) and Hybis (Fig. 3), and in-situ data of pH, pCO_2 and ORP ware measured every 2 seconds during observation. The sensor which was installed to the AUV was connected to the data processor of AUV through a RS232C cable, and was supplied electric power from the AUV. The sensor which was installed to the CTD-CMS and Hybis was attached in stand-alone (self-recording and own power supply).

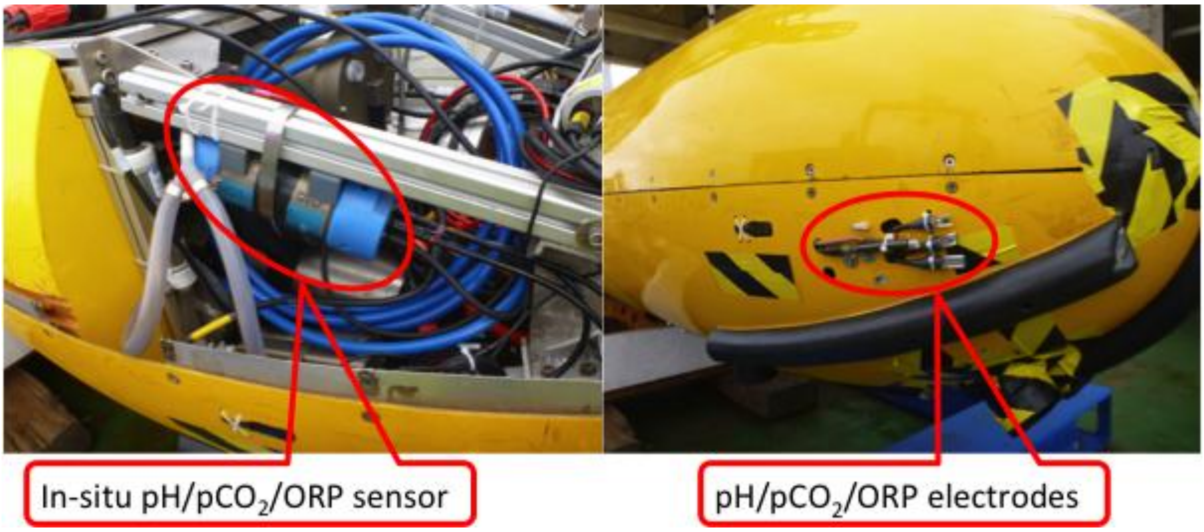

Fig. 8.1 The in-situ pH/pCO_2/ORP sensor which was installed to the AUV.

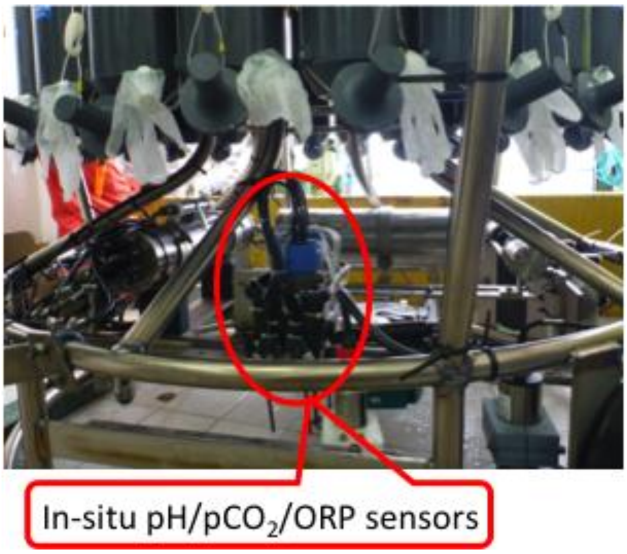

Fig. 8.2 The in-situ pH/pCO_2/ORP sensors (two sensors) which were installed to the CTD-CMS.

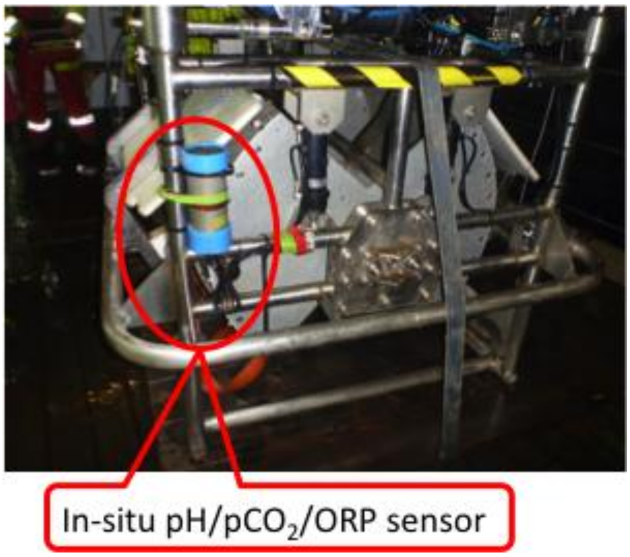

Fig. 8.3 The in-situ pH/pCO_2/ORP sensor which was installed to the Hybis.

Results

For example, the result in the Autosub68 mission is shown in Fig. 4. In this mission, the AUV cruised four lines in north-south direction. The small decrease of pH and increase of pCO_2 (areas A, C, D and F) were detected in four cruising lines. The areas of low pH and high pCO_2 were in two southernmost areas (B and E), and the pH in area B was lower 0.01pH than area E though the depth was almost same in both areas. These results suggest that there are low pH and high pCO_2 seawater near bottom in area B and there are the slightly low pH and high pCO_2 seawater area A, C, D and F. On the other hand, the result of ORP was different from them of pH and pCO_2, because ORP respond to H_2S and/or charged suspended matter, not CO_2.

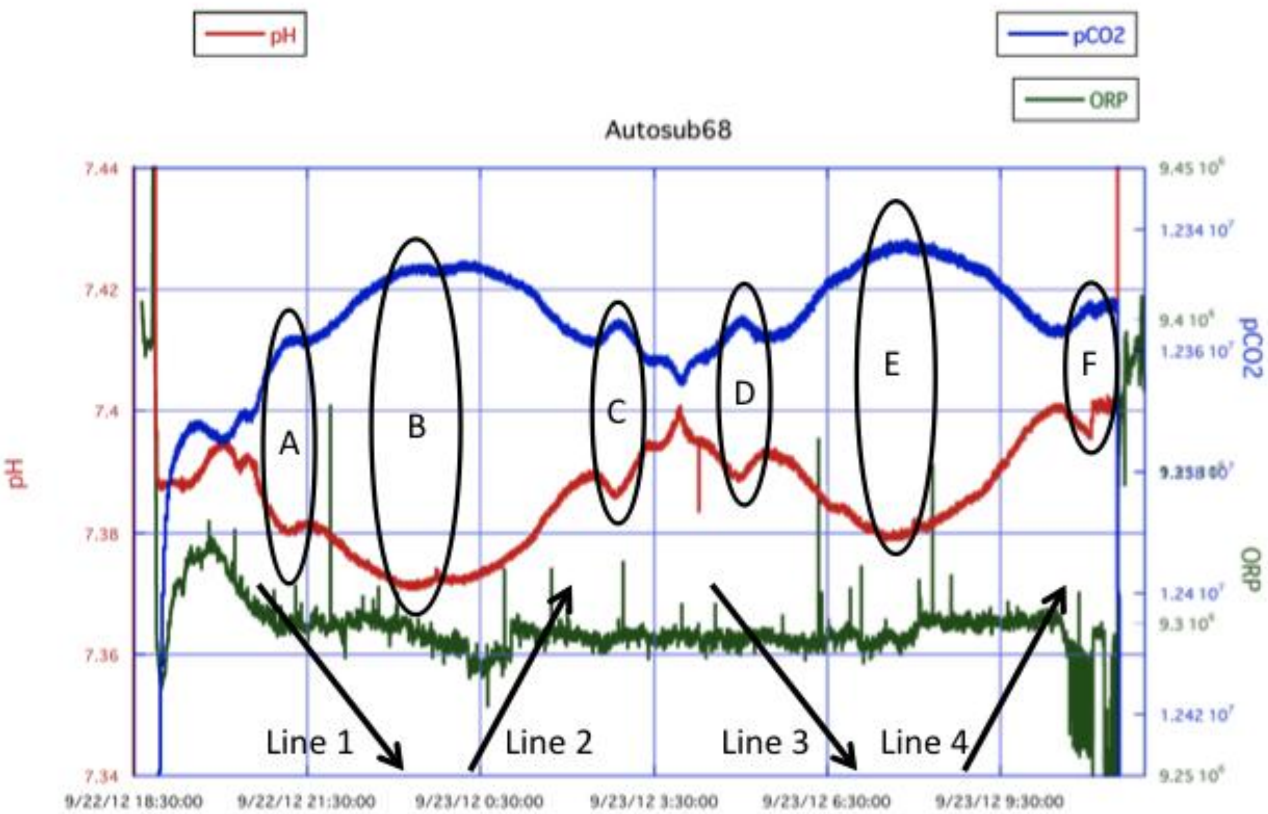

Fig. 8.4 The results of in-situ pH, pCO_2 and ORP observation in the Autosub68 mission.

I plan to draw up detail horizontal and vertical contour maps of pH and pCO_2 in the Sleipner Site by using in-situ pH and pCO_2 data that are obtained by AUV and CTD-CMS observations for the assessment of CO2 leakage at the site.

Section 9. JC077 NMFSS Ship Fitted Systems

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Meteorology monitoring package.

The Surfmet system was run throughout the cruise. Please see the separate BODC information sheet JC77_Surfmet_sensor_information_sheet.docx for details of the sensors used and the calibrations that need to be applied. The calibration sheets are included in the directory Ship_Systems\Met\SURFMET\calibrations on the final ships data disk.

Pumped sea water sampling system [hull bottom intake]. Sea surface monitoring system [salinity, temperature, transmissometre, fluorimetre].

The Surfmet system was run throughout the cruise. Please see the separate BODC information sheet for details of the sensors used and the calibrations that need to be applied. No problems were encountered. The calibration sheets are included in the directory Ship_Systems\Met\SURFMET\calibrations on the final ships data disk.

Ship scientific computing systems.

Data was logged by the Techsas data acquisition system into NetCDF files. The format of the NetCDF files is given in the file NMFSS_NetCDF_Description_Cook.docx. The instruments logged are given in JC77_Ship_fitted_information_sheet_JC.docx. Data was additionally logged into the RVS Level-C format, which is described in the same document. Tim LeBas from NOC Southampton processed the 710 multibeam data using his own Caris package.
The Level-C software was run on the new Sun Enterprise Sparc server. The Enterprise does not have a monitor output and so the fromtechsas program was started remotely and run in the background. This worked well and there were no problems when the xterm that it was started in was closed. The Cook file server was used to provide a network storage area which was used to provide shared storage for everyone to use. This was copied to the end of cruise data disk.

Kongsberg EA600 12 kHZ single beam echo sounder.

The EA600 single beam echo sounder was run throughout the cruise. The results are typical for this vessel with lots of aeration under the hull and some poor performance from the acoustic systems in rough weather. During the cruise this could also be seen in the EM710 multibeam and EK60 multi frequency sounder underway data. The underway depth data logged is therefore of variable quality with lots of spikes and gaps as a result. Before using depth data from the EA600's NetCDF file the .bmp files should be consulted to see if the depth data for that time period was reliable. The EA600 was used with a constant sound velocity of 1500 ms^{-1} throughout the water column to allow it to be corrected for sound velocity in post processing, though corrections would be very minor with water depths of typically 85m.
All systems were turned off during all AUV deployments.

Kongsberg EM710 SHALLOW/MID Water Multi beam echo sounder.

It was also run throughout the cruise to provide general depth information.
The EM710 suffered from some poor performance due to aeration caused by the vessel’s pitching motion, although to a slightly lesser extent than the EA600. The drop keel was flush with the hull for the whole of the cruise as a data calibration of the transducers was required and subsequent movement of the drop keel would have rendered this calibration invalid.
EM710 water column data are logged within the Kongsberg raw all files during the complete survey. This data greatly adds to the size of the raw files. It was decided that logging in this way was the most likely to cater for all possible future post processing requirements. As post processing requirements become clearer it may be more convenient on future cruises to collect water column and bathymetry data into separate files, this would certainly make the processing of the bathymetry quicker.
Olex was run throughout the cruise and was useful for identifying sites to sample at and the location of the vessel relative to the next station.

Sound Velocity Profiles.

The sound velocity profile data are included on the data disk from CTD casts.

75 kHz and 150 kHz hull mounted ADCP system.

Neither was run on the cruise as considerable compromise with the EK60 and EM710 data logging rate would have been required. Also some acoustic interference would have been inevitable.

Wave height recorders.

The antenna unit for the Wamos wave radar was run for part of the cruise for test and calibration purposes and the data collected included on the final data disk in the WAMOS directory.

CTD.

The CTD data is included on the data disk in Specific Equipment\CTD\.

EK60

EK60 data was collected throughout the cruise and the system setup with a two second ping rate and pulse length of 1024 uS and sample length of 256 uS. The recommended/default power settings for the transducers were used.
Transducers frequencies of 18Khz, 38Khz, 120Khz and 200Khz were recorded. The 70Khz transducer was not run as previous experience on past cruises had shown that data from the EM710 water column was significantly degraded when both these instruments operate at the same frequency.

Section 10. Summary and Conclusions.

The cruise was a great success and demonstrated the ability to perform large aerial surveys over relatively short time periods. These surveys were complemented with a water sediment sampling programme where targets were located using the on-board and AUV sensor systems. We completed over 1300 km of survey lines and produced high quality multibeam maps that covered 246 km^2 of seafloor. The chemical sensors on both the AUV, CTD and Hybis revealed areas enriched with methane and reduced species. The work will continue on the samples back at NOC.

Appendix 1

Instructions for Autosub 6000 Edgetech data processing

1. Data appears as a series of DAT000xxx.jsf files these need to be converted to XTF format using the **Discover 4200 MP 2.03** program.
2. Click the **Configuration....Record** menu item and tick the **XTF Output** box
3. On the tabs at the bottom click the **Disk** tab. On this set the record file directory to where you wish the xtf files to be kept. 

4. Before recording the xtf files the video gains will need to be set. Choose one jsf file for playback, set it playing and possibly increasing speed using the  button. Then select the **VideoGains** tab and hit **Normalise**. This will set an instantaneous gain levels for **Gain** and **TVG**. Average setting is Gain 29dB and TVG 18dB/100M but look at imagery to confirm.
5. Back to the **Disk** Tab. Select a Playback file and as soon as it starts hit the record button. Speed the process up by using the  button - max speed is 20.
6. Proceed through <u>all</u> the jsf files in order, waiting for each to finish after a initial speed up. This is slow and laborious. Ignore the Data written tally, each xtf file has a maximum size of about 280Mb. It will also create new jsf files - these can be deleted.
7. Once finished all the DAT000xxx.jsf files then move to **PRISM**.
8. Create directories and sub-directories for the cruise, autosub and the mission name and cdf. e.g. /home/tlb/JC77/autosub/m59/cdf and another directory for nav
   e.g. /home/tlb/JC77/autosub/m59/nav
9. In the cdf directory make a file listing all the high frequency (or low but not both) xtf files on the windows disk. e.g
   ls /cdrive/Users/tlb/Documents/JC77/autosub/m59/xtf/*H.xtf > highlist
10. In the same directory use the loopfile command to convert all the xtf files to Netcdf format. Sub-sampling is suggested as the data across track is of considerably higher resolution across track than along-track. Example: On JC77 the HF data was 1.2cm resolution by 29.7cm ping spacing.
    e.g. **loopfile reson2prism m59 highlist cdf 1 -z 31 -a 4400 -f 5**
    The parameters are:
    a. **reson2prism** - conversion programme
    b. **m59** - mission number
    c. **highlist** - list of xtf files (including pathname)
    d. **cdf** - output datatype

    e. **1** - starting pass number
    f. **-z 31** - UTM zone 31
    g. **-a 4400** - Number of samples in output file (22160 on input)
    h. **-f 5** - Sub-sampling factor of input imagery

11. A separate navigation file should be available from the Autosub team. This is a ASCII text file with columned data: Mission, Date, Time, Lat, Long, Head, Roll, Pitch, Depth, Altitude
12. Put this file in the nav directory and edit it and remove the headings wording (first line) and then save as a **nav** file e.g. **m59.nav**
13. Run **wireout** to produce a veh_nav file . Zero cable out value and Zero added minutes and weight is immaterial.
14. Create a **commands.cfg** file for the type of sidescan data. For example high frequency sidescan:

    addnav -i %1 -o %0 -s 1.0
    widealt -i %1 -o %0 -p
    mrgnav_inertia -i %1 -o %0 -u 0 -r 0.0,0.0 -n navfile.veh_nav
    edge16 -i %1 -o %0 -m
    shade_tobi -i %1 -o %0 -n 1000
    tobslr -i %1 -o %0 -r0.0576 , res # high freq 110m 6 Hz subsamp 5
    filter -i %1 -o %0 -b 1,351 -h -v 1,5000
    filter -i %2 -o %0 -b 21,351 -l -v 1,5000
    wtcombo -i %2 , %1 -o %0 -c 1,1
    restorehdr_tobi -i %1 -h %5
    widealt -i %2 -o %0 -h -l 500

15. Go to the cdf directory and choose a sample middle cdf file and draw a **profile** across track of the pixel values on one line to find a threshold value from background water column to first return.

    e.g. **profile m59p20.cdf 100**

    The parameters are:

    a. **m59p20.cdf** - chosen file
    b. **100** - line number

    Example: Value of 250 if peaking at 1000 and background is 0-40.

16. Test the files for time continuity

    e.g. **do_test_times m59 1 63 0.2**

    The parameters are:

    a. **m59** - mission name
    b. **1** - first pass number
    c. **63** - last pass number
    d. **0.2** - pulse repetition rate

    If time jumps (backward) use dk2dk_tobi to divide up the files

17. Create an .index file for all the cdf files

    e.g. **do_create_index m59 1 63**

    If the m59.index has conflicts of time these must be solved before continuing. It may useful to copy the index file to the main directory.

18. The data has no altitude values and these must be calculated from the first return.

    e.g. **do_alt_index m59.index 250 13.2 normal 1 n**

    The parameters are:

    a. **The name of the index file to run** (e.g. m59.index)
    b. **Threshold of water column** (e.g. 250)
    c. **The starting altitude** (e.g. 13.2m)
    d. **Type of Bottom** (rocky, default, normal or smooth)
    e. **Speed of detection** (default 10 times) 1 is best
    f. **View results** (default is y) for checking
    g. **Any options you require (e.g. -t -m 10)**

        -n use starboard side only on altimetre correction

        -t use port side only on altimetre correction

        -m clean water column for given value depth in metres

19. The altitude values are in .cdfnew files and need to be renamed to .cdf

    e.g. **renaming cdfnew cdf**

20. In the main directory the data is now ready to run **maptile** to produce the tile areas.
21. Finally run **prism5** in the main directory, insert the correct parameters and **run all maps**

Appendix 2: Summary of JC77 HyBIS Dive Logs

JC77 Station no.	Dive no.	Start of Dive	End of Dive	Comments
JC77-5-185	124	259/1956	259/2131	Grab sample taken at 2109, Downward camera back to front
JC77-5-203	125	260/1830	260/1955	Grab sample taken at 1938, EH-sensor attached to the front of the vehicle
	126	260/2027	260/2048	Dive abandoned due to camera malfunction
JC77-5-204	127	260/2100	260/2201	Grab sample taken at 2142
JC77-2-222	128	261/2000	261/2121	EH-sensor attached to the front of the vehicle
JC77-2-223	129	261/2151	261/2323	EH-sensor attached to the front of the vehicle
JC77-7-251	130	262/2118	262/2330	EH-sensor attached to the front of the vehicle
JC77-7-252	131	262/2359	263/0046	Grab sample taken at 0032, EH-sensor attached to the front of the vehicle
JC77-2-274	132	263/1949	263/2102	EH-sensor attached to the front of the vehicle
JC77-2-275	133	263/2111	263/2307	EH-sensor attached to the front of the vehicle
JC77-5-303	134	265/0020	265/0223	Grab sample taken at 0221, EH-sensor attached to the front of the vehicle