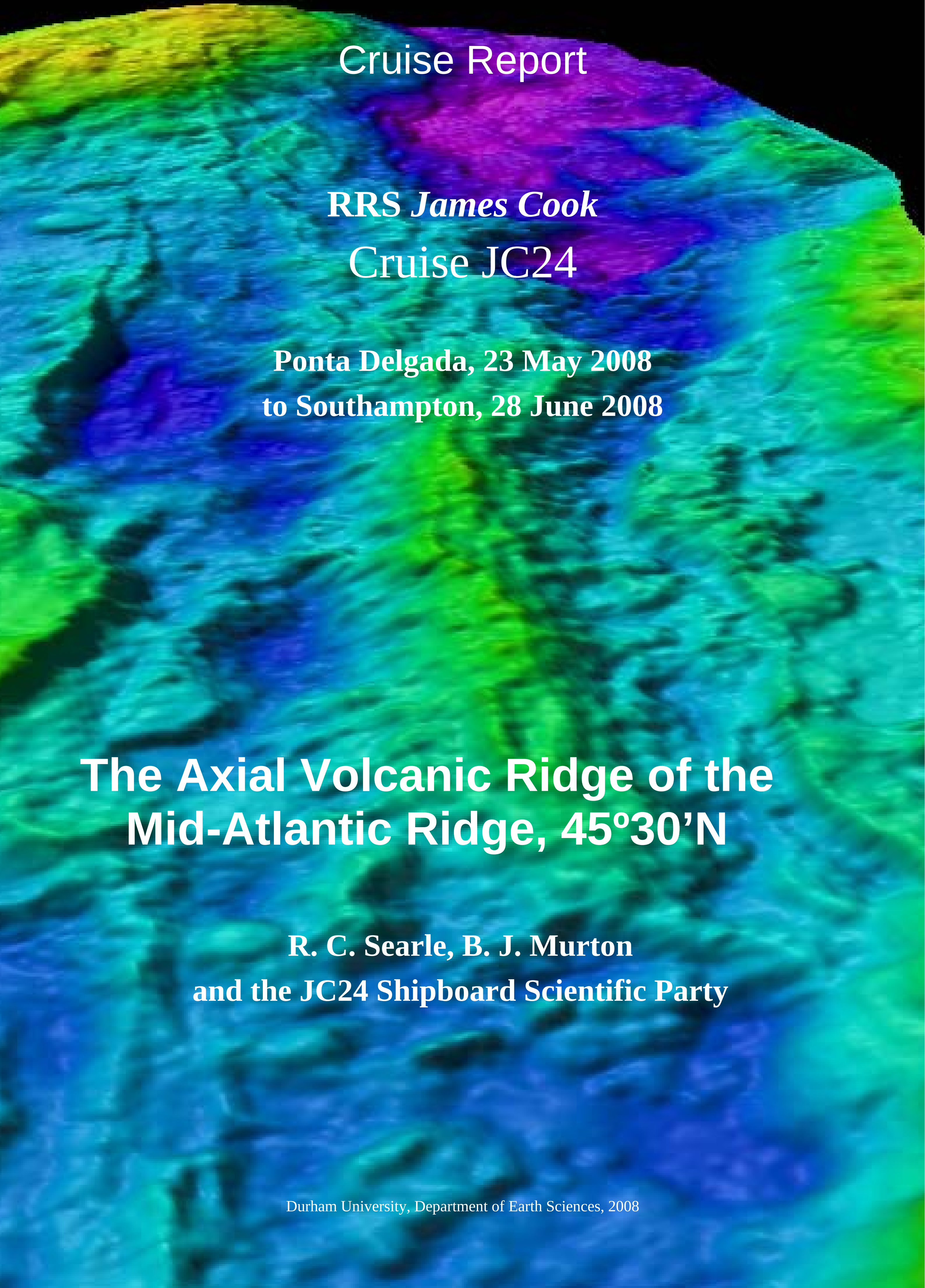

Cruise Report

RRS *James Cook*

Cruise JC24

Ponta Delgada, 23 May 2008
to Southampton, 28 June 2008

The Axial Volcanic Ridge of the Mid-Atlantic Ridge, 45º30’N

R. C. Searle, B. J. Murton
and the JC24 Shipboard Scientific Party

Durham University, Department of Earth Sciences, 2008

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Contents

Personnel

Science party

Roger Searle	Durham University	Principal Scientist
Bramley Murton	National Oceanography Centre	Co-investigator
Maurice Tivey	Woods Hole Oceanographic Institution	Project partner
Peter Van Calsteren	Open University	Project Partner
Tim Lebas	National Oceanography Centre	
Kay Achenbach	University of Wyoming/Durham University	Post-doctoral researcher
Nicole Schroth	National Oceanography Centre	Post-doctoral researcher
Chris Mallows	Durham University	PhD student
Isobel Yeo	University of Edinburgh/Durham University	PhD Student
Kirsty Morris	National Oceanography Centre	PhD student
Chris Waters	Woods Hole Oceanographic Centre	PhD student
Pedro Ferreira		Guest investigator

NMF-SS Science Support Team

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James Wherry	NMF	Isis
Pete Mason	NMF	Isis
Simon Dodd	NMF	Isis
Bob Keogh	NMF	Isis
Will Handley	NMF	Isis
Jim Cooper	NMF	TOBI/Isis
Duncan Matthew	NMF	TOBI
Paul Duncan	NMF	Computing/shipboard instruments
Chris Barnard	NMF	Computing/shipboard instruments

Ship's crew

Antonio Gatti	Master
Peter Reynolds	First officer
Phil Oldfield	Second Officer
Keiron Hailes	Third Officer
Bernard McDonald	Chief Engineer
Andrej Muravjov	Second Engineer
Christopher Uttley	Third Engineer
John Hasling	ETO
Vivian Wythe	Deck Engineer
Des Reid	Purser/Catering Officer
Kevin Luckhurst	CPO Deck
Mark Squibb	CPO Science
Stuart Cook	SG1A
Gerald Cooper	SG1A
Steven Duncan	SG1A
William McGeown	SG1A
Spencer Payne	SG1A
Emlyn Williams	Engine Room PO
Mark Preston	Head chef
Darren Caynes	Chef
Graham Mingay	Steward
Amy Whalen	Catering Assistant

Introduction and Background

Roger Searle

Axial Volcanic Ridges (AVRs) are common features of slow-spreading mid-ocean ridges {Parson et al., 1993; Lawson et al., 1996; Briais et al., 2000}. They provide an accessible record of MOR volcanism and its variation over time and space, although the time-scale of their development is poorly constrained. Hypothetical development cycles for AVRs have been proposed {Parson et al, 1993; Smith & Cann, 1999; Briais et al., 2000}, but were yet to be tested. Cruise JC24 used the state-of-the-art ROV Isis in an international collaboration to address these questions via a detailed case study of the architecture and chronology of a typical AVR near 45°30'N on the Mid-Atlantic Ridge (Fig. 1).

Many studies have broadly elucidated the structure and volcanic and tectonic processes active at AVRs {Parson et al., 1993; Lawson et al., 1996; Searle, Cowie et al., 1998; Escartin et al., 1999; Briais et al., 2000; Smith, Tivey et al., 1999; Smith & Cann, 1992; Smith, Cann, et al., 1995; Smith & Cann, 1999}. The great majority of surveyed spreading segments on slow-spreading MORs (90% on the MAR) are characterised by AVRs {Lawson et al., 1996 ; Smith & Cann, 1992; Parson et al., 2000}. AVRs are a few kilometres wide and tens of kilometres long, sit above the plate boundary and constitute the youngest crust (Figure 1). They are built by fissure and other volcanism, and appear to be episodic in their evolution. Since seafloor tectonism accounts for only a small proportion of the total extension at these MORs {Escartin et al., 1999}, most melt injected into the crust must eventually lead to surface eruptions, which are mostly concentrated in the AVRs. Axial volcanic ridges thus hold an important record of the nature and fluxes of melt from the mantle.

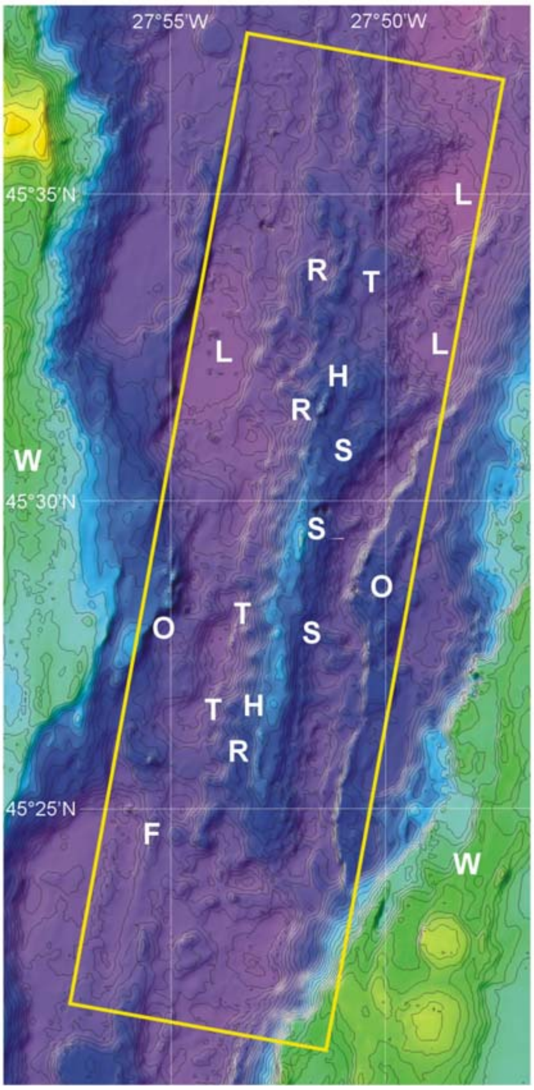

Fig. 1. AVR at MAR 45°N. Bathymetry, 2300 m (green) to 3600 m (purple), contour interval 50 m, illuminated from NW [Ref. 5]. AVR runs NNE through centre of figure. Features, marked by letter to their immediate left, are: F, flat-topped volcano; H, hummocky volcano; R, fissure ridges; S, lateral spurs; T, lava terraces. Flat-lying areas L are probable sites of smooth lava flows. O, parts of older, faulted AVRs in rift walls, W. Box shows approximate extent of DSL-120 survey. Within this we will place approximately 20 cross-axis lines and four detailed boxes for imaging and magnetics using ABE, with 3 along-axis lines, 10 cross-axis lines and two detailed boxes for imaging sampling and magnetics using ISIS.

<u>*Structural elements.*</u> AVRs are built of distinct elements that reflect the changing conditions and history of melt supply and eruption. Ubiquitous volcanic *hummocks* are a few tens of metres wide and built of pillow lavas or tubes. They are often aligned in small *hummocky*- or *pillow-ridges* parallel to the MOR axis, which are interpreted as the surface manifestation of fissure eruptions{Head et al., 1996}. Hummocks often clump together to form larger, central seamounts or *hummocky volcanoes*. Discrete *flat-topped seamounts* 1-2 km in diameter are common both on and off AVRs, but their relation to AVRs was uncertain {Lawson et al., 1996}. Lateral spurs on AVR flanks are proposed to be secondary features fed via channels from primary sources near the AVR axis and include *lava terraces* and *lava ponds* {Smith & Cann, 1999}. *Smooth lava flows* (possibly but not always sheet flows) are rare within AVRs, but often occur in their flanking lows; they are common in segments lacking AVRs and may be precursors to the full AVR {Briais et al., 2000}, although this is still uncertain {Smith et al., 1995; Head et al., 1996}.

Although these diverse volcanic elements have been identified, we lack detailed, quantitative information on their volume, lava run-out length, rate and duration of eruptions, their temporal position in the history of construction of the AVR (e.g. whether central volcanoes are late features); and their relationship to mantle source, sub-surface magma storage, and melt migration processes. Models differ as to whether each individual volcano (of which many hundreds compose a single AVR) may be fed by a separate crustal magma chamber {Smith & Cann, 1992}or whether groups of volcanoes may be fed by one chamber.

Evolution. Despite their near ubiquity, AVRs are not steady-state features. Relatively undeformed AVRs often abut, with a sharp contact, seafloor that is intensely fissured, faulted or sedimented {Lawson et al., 1996; Briais et al., 2000}, implying a hiatus prior to new AVR construction. Thus, AVRs are essentially episodic, and successive construction zones may migrate across the median valley (MV) floor{Lawson et al., 1996; Ballard & Van Andel, 1977}. Study of the variations among AVRs has led to the development of an evolutionary model {Parson, 1993; Lawson, 1996; Searle, 1998; Smith & Cann, 1999}, (Fig. 2). In this model, extensive, high-effusion rate smooth flows reflect arrival of a new batch of relatively primitive melt from the mantle. Subsequent fissure eruptions produce hummocky volcanic ridges and marginal terraces. As the magma differentiates and magma flux wanes, fissures partly close and remnant high-level magma pockets feed more evolved flows that centralise into a few large hummocky or flat-topped volcanoes. Finally, faults disrupt the AVR as magma flux ceases.

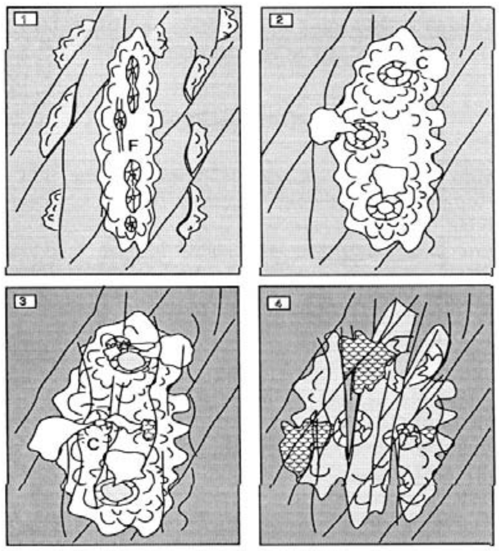

Fig. 2 Model of AVR evolution
{Parson et al., 1993}

This evolutionary model has never been tested. We do not know the geochemical, spatial or temporal relations between the sources of the individual volcanic elements or between successive AVRs, though we hypothesise that varying melt production and effusion reflect heterogeneity and variations in fusibility of the mantle source. Until now it has been difficult or impossible to date active AVRs, since they fall within the Brunhes magnetic polarity chron (0-780 ka). *Relative* ages have been estimated, but are uncertain and range over almost two orders of magnitude; estimates of lava ages within an AVR range from <1 ka to at least 20 ka {Lawson, 1996; Ballard & van Andel, 1977; Bryan & Moore, 1977}, while the estimated time between successive AVRs ranges from 25 ka {Ballard& van Andel,, 1977; {Barclay et al., 1998} to 600 ka {Searle et al., 1998; Thatcher & Hill, 1995}.

We used a combination of four approaches to answer these questions: comprehensive, high-resolution morphological and imaging studies to characterise and relate different volcanic landforms (e.g. mapping different lava units and determining stratigraphic relations); measurement of bariations in the strength of crustal magnetisation (a proxy for age), and high-density, precisely located sampling for geochemical analysis and high-precision radiometric (U-series) dating.

Objectives

Our specific objectives were:

1. To determine the life-cycle of an AVR (estimates range from 10ka to 500ka).

2. To test whether the AVR ha a common parental magma derived from a single pulse of mantle melt.

3. To test whether AVRs develop systematically with an evolving volcanic style (e.g., sheet flows > pillow ridges > central volcanoes).

4. To determine how, if at all, these different volcanic components are linked. Are they derived successively from separate magma reservoirs? Are lateral terraces fed from axial vents?

5. To examine whether effusion rate and volume vary with time during AVR development. Are they reflected in volcanic style, run-out length and eruptive position within the AVR?

Summary

Roger Searle

JC24 involved the first use of the ROV Isis on an active mid-ocean ridge axis. We departed Ponta Delgada on 23 May 2008 and finished in Southampton on 28 June. A breakdown of the Isis winch on 9 June required us to return to Ponta Delgada to pick up a spare part, involving a loss of four days. Altogether, we spent approximately 9.5 days on passage and 26.5 days on station at 45° 30'N, including one day lost due to bad weather (Figure3). We completed a 6-day TOBI survey extending approximately 30 km along axis, completely insonifying the AVR with both north- and south-looking sidescan and phase data and obtaining three-component magnetic data on 22 E-W tracks spaced 1.5 km apart (Figure 3). Ship-based EM120 multibeam echosounder (Figure 4) and gravity data were logged throughout the cruise, and sea-surface magnetometer was logged during the passage to and from the study area and during the TOBI survey. Eleven Isis sampling and video imaging dives were completed, and a further two dives carried out detailed bathymetry surveys (Figure 5). 270 rock samples were acquired (Figure 6). A WHOI three-component magnetometer was carried on all Isis dives.

The sidescan data were fully processed on board. In addition to the expected hummocky and flat-topped volcanoes, they revealed a number of lateral hummocky spurs either orthogonal or oblique to the main AVR axis, several areas of uniform, mid- to high-backscatter around the base of the AVR that we interpreted provisionally as sheet flows, and series of small N-S faults and fissures, both on the median valley floor to the west, and within the AVR itself. Separate mosaics of north-, south-, and E-W-looking sidescan were produced, and used extensively in hard-copy and in ArcGIS and Fledermaus software packages both for geological interpretation and for planning dives and other operations.

The TOBI total field magnetic data were reduced to crustal magnetisation. They revealed a stronger magnetisation in the southern, more topographically robust part of the AVR, suggesting it might be younger than the northern more subdued part. The peak magnetisation was very close to the southern tip.

TOBI also carried four Mini-Autonomous Plume Recorders (MAPRs {Baker & Milburn, 1997}) on a penant below the vehicle to reconnoitre for hydrothermal plume activity. The MAPR recorders proved rather unreliable, but some useful data were acquired; they revealed two plume, one in the region of an extensive lava flow in the northeast, and another on the eastern flank of the southern AVR. MAPRs were also mounted on Isis during survey dives that were run at approximately 100 m altitude.

We began Isis operations with two dives (79 and 80, sequentially numbered through successive cruises from the beginning of Isis operations) to investigate the eastern median valley wall and the eastern flank and the axis of the southern, topographically most robust part of the AVR. Meanwhile analysis of the TOBI data had revealed an extensive area of apparently young sheet flows adjacent to the AVR in the northeast, and two dives (81, 82) investigated those. Dives 83 and 85 (84 having been an abortive launch) targeted the central western flank and adjacent median valley floor and valley wall fault scarp. Dive 86 was also an abortive launch. Dive 87 carried out a high-resolution bathymetric and magnetic survey across the northern part of the AVR that included an apparently old flat-topped seamount on the AVR and a volcanic spur of the AVR that appeared to have partly buried an outward-facing fault scarp at the AVR edge. This survey used the Mesotech Systems MS2000 (sometimes also referred to as SM2000 or SM2k) sonar and WHOI magnetometer on Isis. Dive 88 investigated the southernmost tip of the AVR and flanking median valley floor of a variety of ages including the areas of highest magnetisation. Dives 89 and 90 returned to the median valley floor in another area of sheet flows and followed an important lateral spur from there up the northeastern AVR flank to its crest.

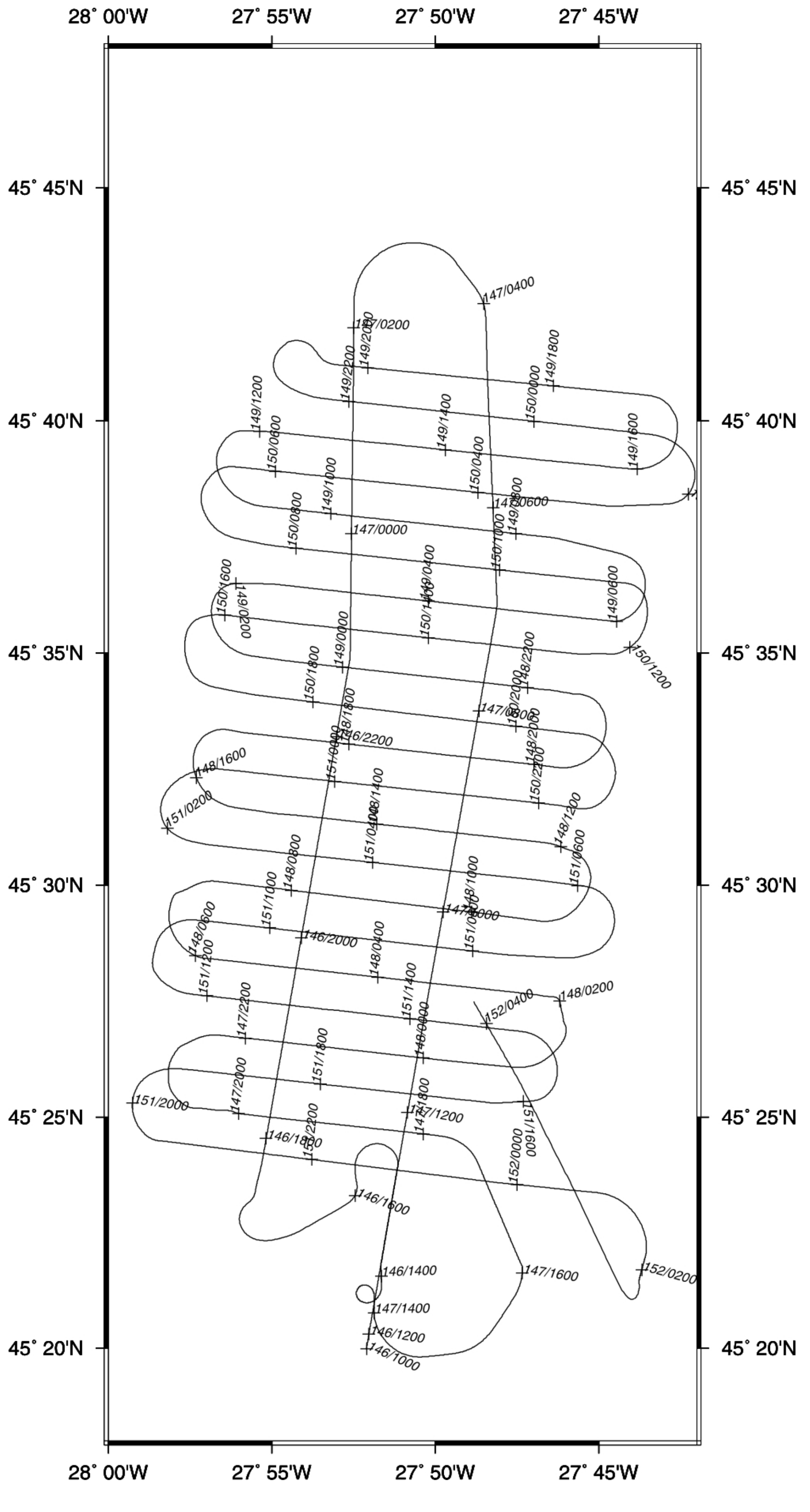

Fig. 3. TOBI track.

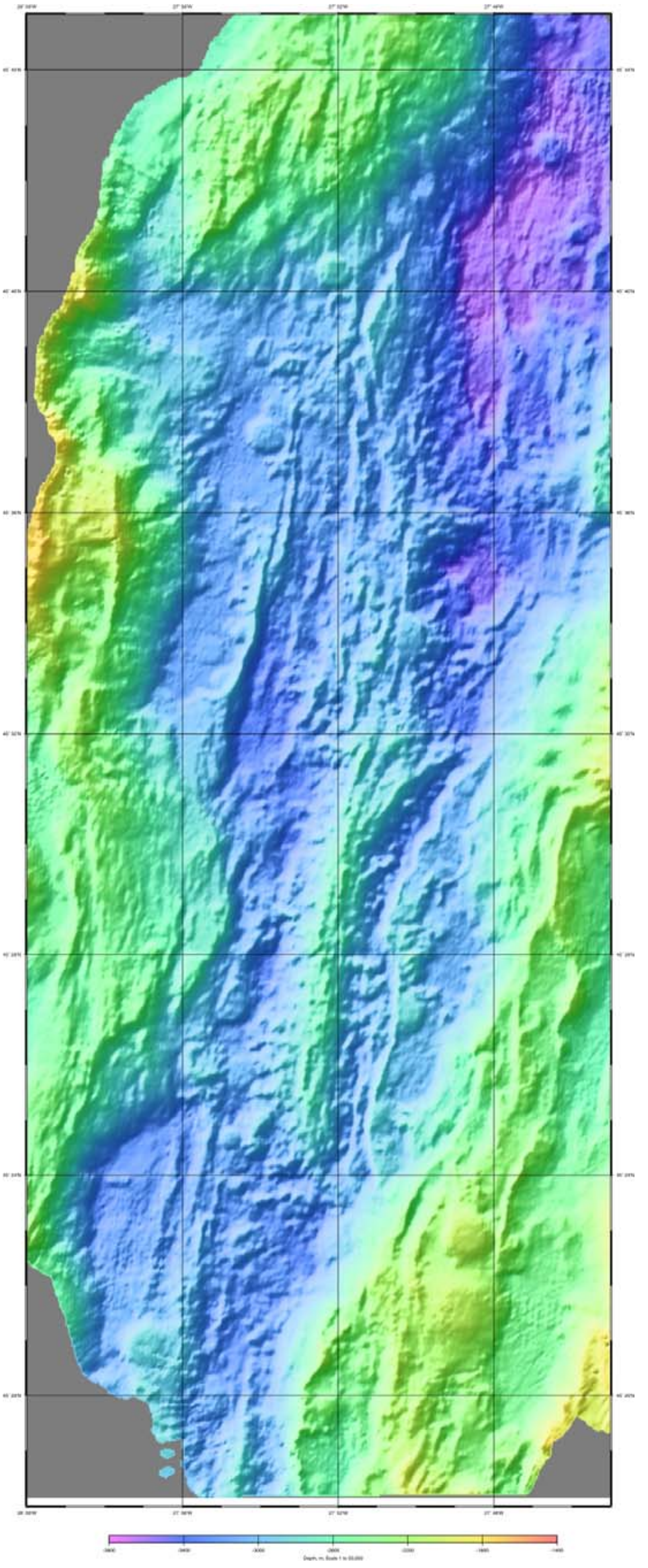

Fig. 4. Shaded relief bathymetric image from all JC24 EM120 data.

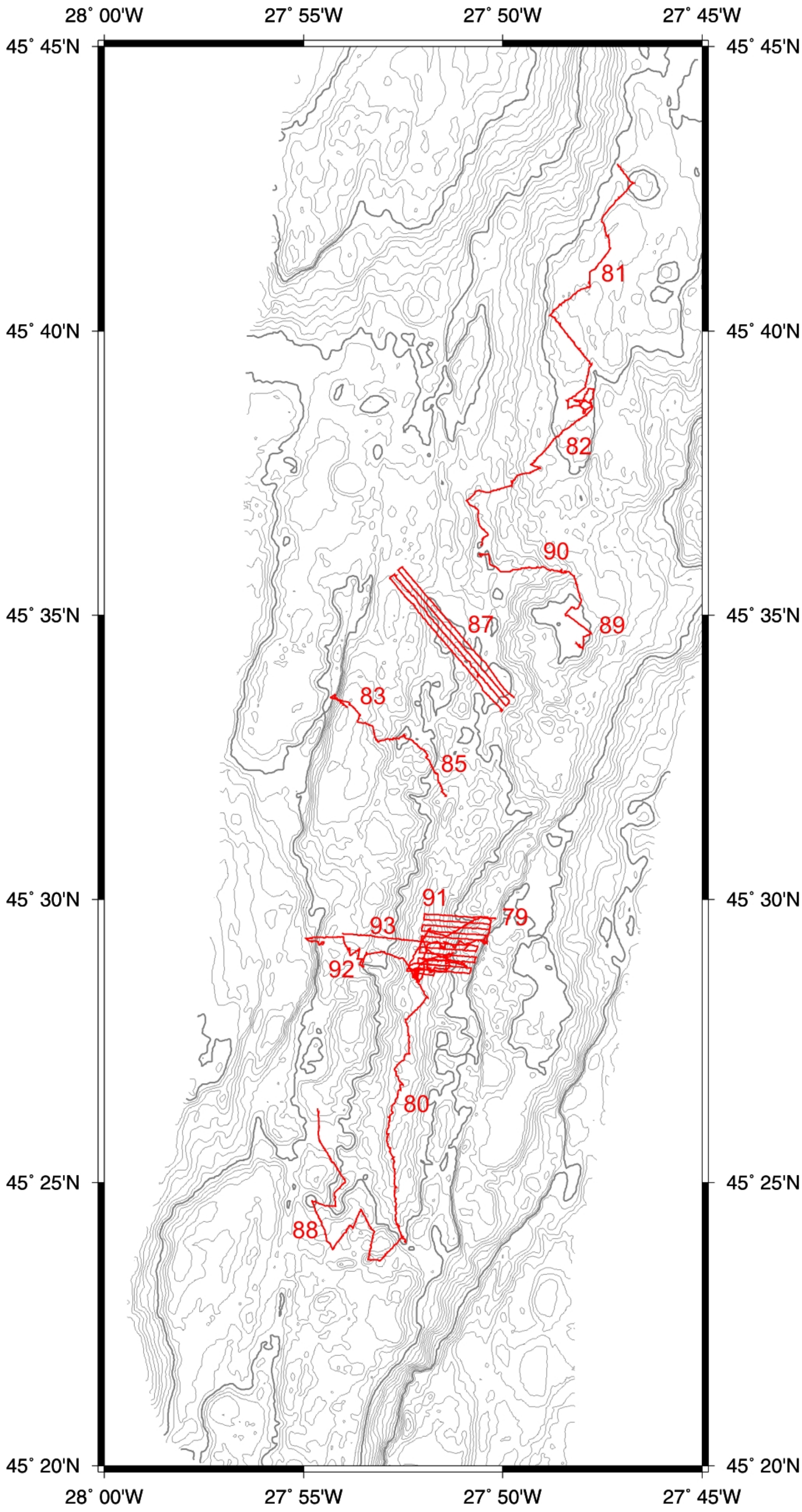

Fig. 5. Isis dive tracks. Contour interval 50m; 500 m highlighted.

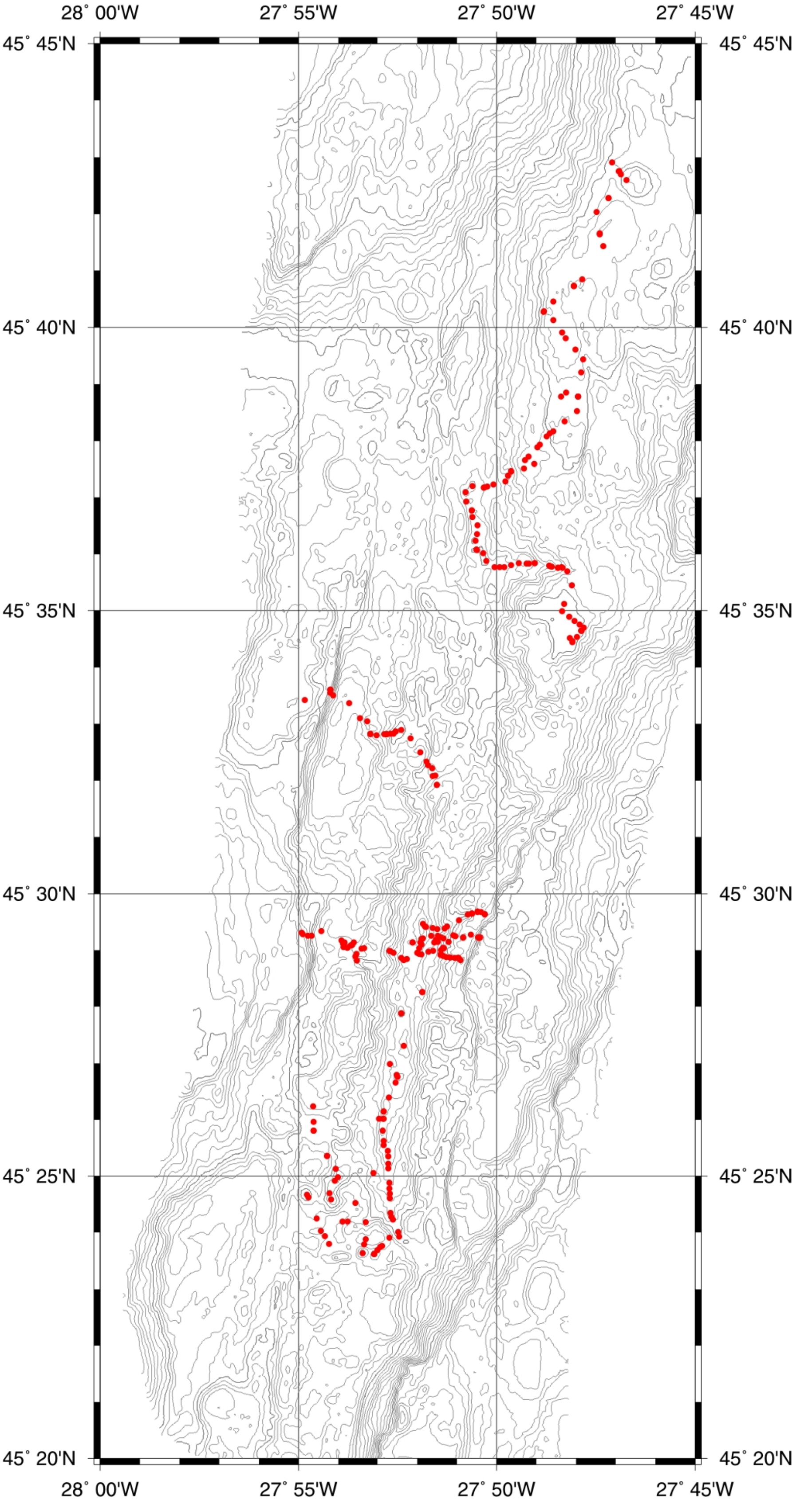

Fig. 6. Isis sample positions. Contour interval 50 m.

The remaining dives were clustered around the central, highest part of the southern AVR, including the area of the hydrothermal plume. Dive 91 was a second MS2000 and magnetometer survey of the eastern flank and crest. Dive 92 provided a traverse of the whole AVR from west to east including the adjacent median valley floor and valley wall scarp in the west, with the eastern part of the profile running through the area of the dive 91 survey. Finally, dive 93 further investigated this area, and ran a magnetic profile westwards to complement those flown during dive 91 on the east flank. A further traverse across the whole AVR between the dive 91 area and the tip had been planned, but bad weather at the end of the cruise prevented us from carrying it out.

In addition to the primary geological objectives, we also took samples of corals on all Isis sampling dives.

Several short periods of Isis downtime, either for maintenance or caused by poor weather, were filled by carrying out "Tow-yo" surveys with MAPR instruments over the areas of plume found during the TOBI and Isis dive 91 surveys. We also took the opportunity to trial the new TV-grab Hybis.

A summary of the time spent on each operation is given in Table 1

Post-cruise work will include:

- topographic, volcanological and tectonic analyses of the sonar, bathymetry and video data (led by Searle);
- further analysis of the TOBI and Isis magnetic data (Tivey);
- petrological, geochemical and isotopic analyses of rock sample (led by Murton);
- magnetic palaeointensity measurements on rock samples (M. Cormier, University of Missouri, a project partner who was unable to join the cruise);
- U-series dating (Van Calsteren and K. Sims, WHOI – second partner who was unable to join the cruise.
- DNA analyses of coral tissues (Morris).

Further petrological and analytical work will also be carried out by co-investigators J. Davidson and Y. Niu, Durham, who were also unable to participate in the cruise.

Table 1: JC24 operations (durations in hours)

Item	Start date	Start Day	Start Time GMT	End Day	End Time GMT	Pas-sage	Transit	TOBI	Isis	SVP	Hybis	MAPR	Contin-gency	Science hours	Science days
In Ponta Delgada		143	9:30	143	9:30	0.0									
Passage	May-23	144	9:30	146	7:40	46.2									
SVP	25	146	7:40	146	11:30					3.8				3.8	0.2
TOBI	25	146	11:30	152	2:31			135.0						135.0	5.6
Transit	31	152	2:31	152	4:36		2.1							2.1	0.1
Dive 79	31	152	4:36	153	5:16				24.7					24.7	1.0
Transit	31	153	5:16	153	6:20		1.1							1.1	0.0
Dive 80	Jun-01	153	6:20	154	16:35				34.3					34.3	1.4
Transit	2	154	16:35	154	18:38		2.1							2.1	0.1
Dive 81	2	154	18:38	156	10:20				39.7					39.7	1.7
Transit	4	156	10:20	156	13:15		2.9							2.9	0.1
Dive 82	4	156	13:15	157	14:14				25.0					25.0	1.0
Transit	5	157	14:14	157	14:30		0.3							0.3	0.0
Hybis	5	157	14:30	157	17:00						2.5			2.5	0.1
Transit	5	157	17:00	157	18:00		1.0							1.0	0.0
Dive 83	5	157	18:00	158	8:16				14.3					14.3	0.6
Transit	6	158	8:16	158	9:08		0.9							0.9	0.0
Hybis	6	158	9:08	158	11:50						2.7			2.7	0.1
Transit	6	158	11:50	158	15:01		3.2							3.2	0.1
MAPR 1	6	158	15:01	159	2:26							11.4		11.4	0.5
Dive 84	7	159	2:26	159	6:31				4.1					4.1	0.2
Dive 85	7	159	6:31	160	2:24				19.9					19.9	0.8
Transit	8	160	2:24	160	4:12		1.8							1.8	0.1
MAPR 2	8	160	4:12	160	23:00							18.8		18.8	0.8
Transit	8	160	23:00	161	0:14		1.2							1.2	0.1
Dive 86	9	161	0:14	161	1:22				1.1					1.1	0.0
MAPR 3	9	161	1:22	161	12:53							11.5		11.5	0.5
Passage	9	161	12:53	163	9:00								44.1	44.1	1.8
Azores	11	163	9:00	163	13:00								4.0	4.0	0.2
Passage	11	163	13:00	165	6:18								41.3	41.3	1.7
Dive 87	13	165	6:18	166	19:00				36.7					36.7	1.5

Table 1 (continued)

		Start		End											
Item	Start date	Day	Time GMT	Day	Time GMT	Pas-sage	Transit	TOBI	Isis	SVP	Hybis	MAPR	Contin-gency	Science hours	Science days
Transit	14	166	19:00	166	20:25		1.4							1.4	0.1
Dive 88	14	166	20:25	168	3:00				30.6					30.6	1.3
Transit	16	168	3:00	168	4:45		1.7							1.7	0.1
Dive 89	16	168	4:45	169	1:07				20.4					20.4	0.8
Dive 90	17	169	1:07	169	17:22				16.2					16.2	0.7
Transit	17	169	17:22	169	18:17		0.9							0.9	0.0
Dive 91	17	169	18:17	171	9:50				39.6					39.6	1.6
Transit	19	171	9:50	171	10:45		0.9							0.9	0.0
Dive 92	19	171	10:45	173	6:26				43.7					43.7	1.8
Transit	21	173	6:26	173	7:16		0.8							0.8	0.0
Dive 93	21	173	7:16	174	16:54				33.6					33.6	1.4
Transit	22	174	16:54	174	21:50		4.9							4.9	0.2
MAPR 4	22	174	21:50	175	10:10							12.3		12.3	0.5
Weather	23	175	10:10	175	23:58								13.8	13.8	0.6
Dive 94	23	175	23:58	176	0:10				0.2					0.2	0.0
Weather	24	176	0:10	176	8:00								7.8	7.8	0.3
Passage to Southampton	June 24	176	0:10	180	8:00	96.0									
Total (hours)						142.2	27.2	135.0	383.9	3.8	5.2	54.1	111.0	720.3	
Total (days)						5.9	1.1	5.6	16.0	0.2	0.2	2.3	4.6	30.0	

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Narrative

All times GMT. Details of individual operations are given in Table 1 and dive summaries are in Appendix 4.

23 May 2008, Julian day 144

0900 GMT Departed Ponta Delgada, on passage to work area.

24 May, day 145

2000: Position 43° 23.0'N, 27° 23.9'W. Scientific watches begin.

25 May, day 146

0740 Position 45° 20'N, 27° 52'W. Hove to at waypoint T0 for Sound Velocity Profile.

0821 Start SVP, with 4 MAPRs on wire for calibration.

0930 Package on bottom

1053 Package on deck; end of station. Proceed to deploy TOBI

1138 TOBI in water.

1234 Begin TOBI magnetic calibration loop.

1345 End of loop. Proceed to **start of TOBI survey**.

1401 Deployed magnetometer.

1404 Poor port phase signal on TOBI. As the AVR (prime target of the survey) would be on port side, decided to reverse survey direction (clockwise rather than anticlockwise).

26 May, day 147

1328 TOBI at end of along-axis survey. Recover magnetometer. Begin turn to port, to start cross-axis survey.

1849 TOBI at T9. Start of cross-axis TOBI survey.

27 May, day 148

TOBI survey continues

28 May, day 149

TOBI survey continues

29 May, day 150

TOBI survey continues

30 May, day 151

2346 **End of TOBI survey.**

31 May, day 152

0004 Magnetometer recovered.

0231 TOBI recovered.

0257 Proceed towards start of first Isis dive.

0455 Deploy Isis.

0507 Problem with Isis CTD – recovered.

0528 Deploy Isis again.

0545 Isis diving – **start of dive JC24-79** to explore southern end of AVR including E flank.

0816 Isis on bottom.

1 June, day 153

0307 Isis leaving bottom (maximum payload reached) – **end of dive 79.**

0450 Isis on surface.

0515 Isis secured. Recovered samples and serviced Isis.

0630 Faults discovered in ship's USBL and on Isis computer.

0842 Problem fixed. Launch Isis.

0920 Isis diving – **start of dive 80** (continuation of dive 79.

1110 Isis on bottom).

2 June, day 154

1400 Isis leaving bottom – **end of dive 80**.

1610 Isis on surface.

1635 Isis secure. S/c to next dive launch point.

1838 On station for next dive.

2007 Deploy Isis.

2026 Isis diving – **start of dive 81** to investigate NE flank of AVR and acoustically bright lava flow to its east.

2240 Isis on bottom.

3 June, day 155

Continue dive 81 all day.

4 June, day 156

0801 Isis leaves bottom (maximum payload reached and oil pressure low?) – **end of dive 81.**

1006 Isis on surface.

1020 Isis on deck. Remove rocks and service ROV.

1315 Deployed Isis.

1327 Isis diving – **start of dive 82** (continuation of dive 81).

5 June, day 157

1219 Isis leaves bottom at **end of dive 82.**

1401 Isis on surface.

1414 Isis on board. Move to launch point for Hybis.

1514 On station.

1542 Hybis launched.

1556 Fault in comms. Hybis recovered.

1633 Move to start point for next Isis dive.

1818 Deploying Isis.

1843 Isis diving **– start of dive 83** (to investigate W flank and central crest of AVR).

2040 Isis on bottom.

6 June, day 158

0606 Problem with Isis manipulator and comms. Leave bottom at **end of dive 83**.

0802 Isis on surface.

0816 Isis recovered.

0908 On station for Hybis deployment.

0936 Hybis deployed.

1150 Hybis recovered after short circuit tripped ship's 40A power supply.

1248 Proceed to start point of MAPR survey.

1501 Deploy MAPRs for tow-yo through hydrothermal plume signal to NE of AVR.

1712 3400 m of cable paid out. S/c 270 ° . **Commence MAPR tow-yo survey 1** from 100 m above seafloor to 3000m below surface.

7 June, day 159

0226 End of tow-yo.

0335 MAPRs inboard. Proceed to start of next dive.

0524 Isis diving **- start of Isis dive 84** from western median valley wall onto western flank of AVR.

0552 Wire fouled camera bar – commence recovery.

0631 Isis inboard at **end of dive 84**.

0822 Damage repaired – re-launch Isis.

0830 Isis diving **– start of dive 85 –** continuation of dive 83. *NB: The Isis team had designated the previous (aborted) dive as 84, and this one as 85. The science team were unaware of this until part way through the dive. Therefore, records of this dive are variously reported as 84, 85, or 84/85. No science data were collected on the dive started at 159/0524.*

1030 Isis on bottom.

2327 Cable observed dragging behind Isis. Investigated and decided to recover.

8 June, day 160

0035 Isis leaves bottom at **end of dive 85.**

0224 Isis in board.

0412 On station for MAPR test on CTD wire..

0455 Commence veering to 1500 m.

0558 Commence recovery.

0745 Commence **MAPR tow-yo profile 2** over E median valley wall and E flank of AVR**.**

2110 Recover MAPRs for start of next Isis dive.

Proceed to start of Isis SM2000 and magnetic survey over N-central AVR.

9 June, day 161

0014 Launching Isis.

0025 Isis dives at **start of dive 86 .**

0053 Sprocket on spooling winch is slipping – commence recovery.

0122 Isis on deck at **end of dive 86.**

Proceed to next MAPR profile, crossing profile 2.

0616 Commence **MAPR tow-yo profile 3**.

1253 MAPRs recovered.

1300 Proceed at full speed to Ponta Delgada to pick up spare sprocket for Isis winch.

10 June, day 162

On passage to Ponta Delgada.

11 June, day 163

0840 Hove to at Ponta Delgada

0920 Pilot aboard.

0930 Secured at jetty. Spare part delivered. Technician ashore for dental treatment.

1318 Underway back to survey area.

12 June, day 164

On passage to survey area.

0529 On station to begin next dive.

0618 Launching Isis.

0630 Isis Dives at **start of dive 87**: swath sonar and magnetic survey over northern part of AVR.

13 June, day 165

Dive 87 continues

14 June, day 166

1730 Isis leaves bottom at **end of dive 87.**

1920 Isis secured.

2026 On station for next dive.

2054 Isis dives at **start of dive 88** around SW tip of AVR..

15 June, day 167

Dive 88 continues.

16 June, day 168

0104 Isis leaves bottom at **end of dive 88.**

0300 Isis inboard. Transit to start of next dive.

0445 On station.

0616 Commence Isis deployment.

0626 Isis dives at **start of dive 89** over sheet flow on E flank of AVR.

2246 Isis leaves bottom at **end of dive 89**.

17 June, day 169

0107 Isis on deck. Immediate turn-round to resume dive.

0329 Isis diving at **start of dive 90 –** continuation of dive 89..

1522 Isis leaves bottom at **end of dive 90**.

1721 Isis on board.

1817 On station for next dive.

1923 Isis diving at **start of dive 91 –** sonar and magnetic survey on E central flank of AVR.

18 June, day 170

Dive 91 continues

19 June, day 171

0754 Isis leaves bottom at **end of dive 91**.

0950 Isis on board.

1045 On station for next dive.

1150 Isis diving at **start of dive 92 –** video and sampling of west-central median valley wall and floor and AVR flank

20 June, day 172

0830 Isis at last planned waypoint with full payload. Worsening weather (wind force 8) prevents recovery, so continue with video survey of AVR crest and potential vent sites.

21 June, day 173

0450 Isis leaves bottom at **end of dive 92.**

0626 Isis on board.

0716 On station for next dive.

0942 Isis diving at **start of dive 93 –** video and sampling in area of dive 91 sonar survey.

22 June, day 174

1110 Last scheduled sampling point for dive 93. Decide to continue with an Isis magnetic survey line over west flank of AVR.

1654 Isis recovered in force 9 at **end of dive 93**. Worsening weather prevents further work pro tem.

2150 **Begin MAPR survey 4** in southern part of Dive 91 survey box.

23 June, day 175

1010 Vessel unable to hold station in force 9. MAPRs recovered at **end of MAPR survey 4**.

2315 Decide to attempt a final Isis dive.

2358 Isis in water, but sea to heavy to complete deployment.

24 June, day 176

0018 Isis secured. Depart work area for Southampton.

Logs

All relevant ship's operations were recorded by the officer of the watch in the ship's "Rough Log" (yellow pages).

The science party maintained a written log (2 volumes of A4 notebook). During the TOBI survey this was typed into an Excel spreadsheet. For Isis dives and MAPR surveys, the written logs were scanned into pdf files (one for each dive or survey).

In addition, during all Isis dives, A3 contoured map sheets were annotated by the lead science observer; these maps were also scanned to pdf at the end of the cruise.

All of the original logs were returned to Durham University at the end of the cruise.

TOBI Operations

TOBI Team: Duncan Matthew, Jim Wherry, ISIS Team

Summary

TOBI was launched and recovered once during the cruise. The times are listed below along with relevant comments:

Deployment	Start time/Day	End time/Day	Comments
Run#1	11:53:58/146	01:26:22/152	Main Survey Area. Two (2) main power re-cycles, early in the run, to try to get port swath working, no joy. Did come back to life 22:17/146 (depth 2700m) and remained functioning right to end of survey.

Total TOBI time collecting data was 5.6 days with a cruise budget of 7 days. No downtime recorded, full survey done in one run.

The TOBI technical specification is given in Appendic 1a; the data format is in Appendix 1b, and a list of Magneto-Optical (M-O) disks used and their relevant numbers, files and times is in Appendix 1c.

System Description

TOBI - Towed Ocean Bottom Instrument - is the National Oceanography Centre's deep towed vehicle. It is capable of operating in 6000m of water. The maximum water depth encountered during the TOBI surveys during this cruise was around 3200m.

Although TOBI is primarily a sidescan sonar vehicle a number of other instruments are fitted to make use of the stable platform TOBI provides. For this cruise the instrument complement was:

1. 30kHz sidescan sonar with swath bathymetry capability (Built by IOSDL)
2. 6 - 10kHz chirp profiler sonar (Built by IOSDL/SOC)
3. Three-axis fluxgate magnetometer. (Ultra Electronics Magnetics Division MB5L)
4. CTD (Falmouth Scientific Instruments Micro-CTD)
5. Pitch & Roll sensor (G + G Technics ag SSY0091)
6. Gyrocompass (S.G.Brown SGB 1000U)
7. Light backscattering sensor (WET labs LBSS)

An Autohelm ST50 GPS receiver provides the TOBI logging system with navigational data. An MPD 1604 9 tonne instrumented sheave provides wire out, load and rate information both to its own instrument box and wire out count signals to the logging system. The instrumented sheave is an optional extra if such an item is not available on the chosen ship. If available, on the ship, then the wire out is recorded on the ship's own data network. This facility was available on the James Cook (JC).

The TOBI system uses a two-bodied tow system to provide a highly stable platform for the on-board sonars. The vehicle weighs 2.5 tonnes in air but is made neutrally buoyant in water by using syntactic foam blocks. A neutrally buoyant umbilical connects the vehicle to the 600kg depressor weight. This in turn is connected via a conducting swivel to the main armoured coaxial tow cable. All signals and power pass through this single conductor.

The deck electronic systems and the logging and monitoring systems were set up in the JC's Main Laboratory on the starboard side. The TOBI replay computer was mounted on the next spare bench space, starboard side. As TOBI has been used previously on the ship, mobilisation of the major components was easily accomplished.

TOBI Deployments

The James Cook (JC) is equipped with a wide stern mounted hydraulic 'A' frame that allows TOBI to be deployed and recovered in an athwartships position. This gives good control of the vehicle during these operations. A main sheave block on the 'A' frame was used for deploying and recovering the TOBI vehicle as well as deploying and recovering the depressor weight and towing the complete system during the survey. No major problems were encountered during any of the launch or recovery operations, which is a very great credit to the deck crew involved.

TOBI Watch Keeping

TOBI watch keeping was split into three, four-hour watches repeating every 12 hours. Watch keepers kept the TOBI vehicle flying at a height of ideally 400 – 600 m above the seabed by varying wire out and/or ship speed. Ship speed was usually kept at 2.0 - 2.5 knots over the ground with fine adjustments carried out by using the winch. As well as flying the vehicle and monitoring the instruments watch keepers also kept track of disk changes and course alterations.

The bathymetry available consisted of previously surveyed blocks of the work area and the JC's EM120 running during the TOBI survey. Both of these aided in determining the flight profile of the vehicle.

Instrument Performance

These are near real-time observations of the instrumentation performance. A more detailed engineering analysis, involving the data collected, will home in any problem areas highlighted by these observations.

Vehicle

During the Run 1 the vehicle performed well apart from a number of remote 'reboots' (6 times logged on TOBI log sheets) of the CTD/Gyro instruments. This was not as frequent as last year on JC007. The new cable and connectors, between the CTD and communications bottle (SIIF tube), have helped immensely in improving reliability but there may still be some issue within the microcontroller software or the CTD itself. The situation will be further tested at base and monitored on subsequent cruises.

Umbilical and Swivel

The umbilical performed perfectly with no faults. We are now no longer using swivels and it has to be noted that overall system reliability has dramatically increased due to this. On this trip there was no down time recorded. It should be noted that the 'umbilical' winch, a former old (>15 years) hydrophone winch, is not up to the job of handling the TOBI umbilical in any sea state. See report by Jim Wherry.

Sidescan

The system performed well with excellent records of mid-ocean ridge structures which aided in planning ROV (ISIS) survey sites later in the cruise.

Magnetometer

The unit worked well throughout the cruise providing valuable data on the spreading ridges in the survey area. The magnetometer was calibrated at start of Run#1 involving 180 and 360 degree turns in the vehicle track, at a shallow vehicle depth (300-400m), prior to descent down to survey altitude (~400m).

Gyro

The unit performed well with the data stream only being corrupted when the CTD locked up. The system returned to normal once the CTD had been correctly rebooted. The gyro proved a valuable aid to processing and geographically referencing sidescan data.

CTD – FSI Serial No. 1429m_16apr99, with new cable and new Subconn connector on SIIF tube

For the majority of the cruise the CTD worked well, although during the survey the unit had to be rebooted numerous times, 6 in-total, during 5.6 days of survey time. This is a great improvement from previous cruises as this total occurrence (6) has been known to be exceeding in just one 4 hour watch. It can be concluded the upgrade of connectors to Subconn types has improved reliability. Further investigation will continue to try and chase down the remaining reason(s) for the CTD to lock up.

The CTD unit has provided valuable data with a possible location of plume up-welling (a large change in salinity measurements). This is being processed by the scientific party.

Pitch/Roll

This unit performed well for the whole cruise.

LSS

The light scattering sensor was used throughout the cruise. Again there is initial indication of variation in data related to possible hydrothermal plumes. This is, again, being analysed by the scientific party.

Swath bathymetry

The unit performed well apart from an initial period of saturation in the port side swath. The planned TOBI track was reversed to make use of the good starboard side looking at the terrain of greater interest. The port side saturation disappeared after 10 hours, in the water, and continued to perform as good as the starboard side for the rest of the duration of the survey. It should be also noted that TOBI was progressively going deeper, passing a TOBI depth of 2700 m, during this time. A fair assumption would be that a connector was the problem source and the increased pressure helped to seat it properly. Further cycling of vehicle depths did not reintroduce the problem.

Deck Unit

The system proved very reliable in operation throughout the cruise. A voltage of 320V was used to power the vehicle with a current of approximately 600 – 700 mA.

Instrumented Sheave

Not required on this cruise, JC had the facilities in place and wire out data made available in a text file.

Winch – TOBI Portable

Not required on this cruise, JC had a fully operational deep tow winch with an inner coaxial cable for power, communication and data streams.

Other Instrumentation – MAPR String

To aid in plume detection 4 self logging devices, Miniature Autonomous Plume Recorders (MAPRs), from Pacific Marine Environmental Laboratory (PMEL), Seattle, WA, U.S.A. were scheduled to be attached to a 200m pennant wire, with a 50kg 'V' shaped tow weight, all attached to the TOBI depressor weight. Since the MAPRs are self-logging no data or power connections to TOBI were required. Prior to the TOBI deployment only 2 MAPRs were fully operational so the wire pennant was reduced to 100m with one MAPR attached a few metres above the 'V' tow weight and the other 50 m above the first. The MAPRs were prepared, serviced and data downloaded by the scientific party. The performance and data analysis, of these devices, is outside the remit of this report. Finally it is noted that we lost the

‘V’ shaped tow weight due to a likely collision with an outcrop on the sea bed (Near Miss Report No: 2008-06-25). The two MAPRs survived and no damage incurred with TOBI or TOBI depressor weight. All instruments were fully functional at the time.

Data Recording and Display

Data from the TOBI vehicle is recorded onto 1.2Gbyte magneto-optical (M-O) disks. One side of each disk gives approximately 16 hours 9 minutes of recording time. All data from the vehicle is recorded along with the ship position taken from the TOBI portable GPS receiver. Data was recorded using TOBI programme LOG.

As well as recording sidescan and digital telemetry data LOG displays real-time slant range corrected sidescan and logging system data, and outputs the sidescan to a Raytheon TDU850 thermal recorder. PROFDISP displays the chirp profiler signals and outputs them to a Raytheon TDU850. DIGIO9 displays the real-time telemetry from the vehicle – magnetometer, CTD, pitch and roll, LSS – plus derived data such as sound speed, heading, depth, vertical rate and salinity.

LOG, PROFDISP and DIGIO9 are all run on separate computers, each having its own dedicated interface systems.

Data recorded on the M-O disks were copied onto CD-ROMs for archive and for importation into the portable (NOC), available on board, image processing system (PRISM).

Deliverable Items

- Copies of M-O data discs on CD-ROM plus associated document header files, numbered 2010 – 2018.
- Real Time thermal printout of raw sidescan (only Time Varied Gain T.V.G. applied).
- Real Time thermal printout of raw non-motion compensated profiler (made available but not generally looked at).
- Copies of raw data (binary format) and digital data, in comma separated variable (CSV) format, on DVDs.
- Digital data stripped out of data files and put in text files (CSV) for easy scientific access.

Summary

The system performed well, overall, with some excellent sidescan imagery and important magnetic data. This provided vital information to aid in nominating sites for ISIS ROV operations later in the cruise. The system will be reviewed, in light of the reported faults, back at NOC in preparedness for further cruises this year. As summarised earlier the proposed survey run was achieved in 5.6 days out of a budget of 7 days, with no down time.

Reference and Contacts

TOBI technical reference: ‘TOBI, a vehicle for deep ocean survey’, C. Flewellen, N. Millard and I. Rouse, Electronics and Communication Engineering Journal April 1993.

e-mail: dlrm@noc.soton.ac.uk,   url: http://www.noc.soton.ac.uk

Acoustic Data Processing

Tim LeBas

1) Navigation

Ship time, position and cable length was gained from the James Cook's in-house database system. The processing system for TOBI image processing (PRISM- Processing Remotely-sensed Imagery for Seafloor Mapping) requires navigational files to be in specific fixed format and thus a format conversion program was written to convert from:

```
08 146 14:33:00  45.378547  -27.857395  1729.2
08 146 14:33:30  45.378814  -27.857297  1744.1
…

to:

jc024        080525 143300  45.378547 -27.857395  1729.20
jc024        080525 143330  45.378814 -27.857297  1744.10
…
```

Points were requested every 30 seconds. Occasionally the winch data was missing signifying that the end was out of the water. To mollify the programs in PRISM all missing cable lengths were converted to zero as they would not be used anyway. The program called "wireout" then estimates the position of a towed body (TOBI) behind the ship. This assumes a given drag and viscosity of cable plus sidescan and assumes a depth value (related to the cable length) and gives an initial estimate of the TOBI position.

2) Simrad EM120 Multibeam bathymetry and backscatter

A. Bathymetry

The data was logged and saved in one hour segments. This still provided a large number of data files (*.all, *.ix1 and *.ix2 files). Processing of these data was done with CARIS HIPS version 6.1. The software is a commercial package running under Windows XP and is highly regarded in the survey industry, however the cost of licences can be prohibitive. The MB system could have been used as it is a UNIX (or Linux) based software package that is freely available at no cost and thus usually attractive to academic research. However the superior editing capabilities of CARIS for removal of spurious data points made it no contest. It is suggested that the ship has its own license for CARIS HIPS as this would assist shipboard computing officers in the time taken to process the data. Typically hand editing of one day's EM120 bathymetry data will take about 20 minutes rather than the 3 hours using the MB or Neptune systems. Automatic filtering routines are available but generally are inferior to human editing.

The setup of CARIS HIPS requires initial configuration of the positioning of the component parts of the system such as the transmit and receive transducer arrays, DGPS receiver, and motion sensor reference unit (MRU). These were measured on the ship to a reference point previously and thus easily entered into HIPS. The measurements were taken from the BLOM survey (done in June 2006) in millimetres are:

	X (+ve stbd)	Y (+ve fore)	Z (+ve up)
DGPS Receiver	509	-2648	31451
EM120 Receive Array	954	14092	-6926
EM120 Transmit Array	1832	19199	-6944
Motion sensor Reference unit	0	0	0

imate ship centre which is calculated from the values put in for length, beam and draught. These are not required in the calculations of multibeam bathymetry

Positions can be verified with HIPS with a graphical diagram in 3D (see Figure 7).

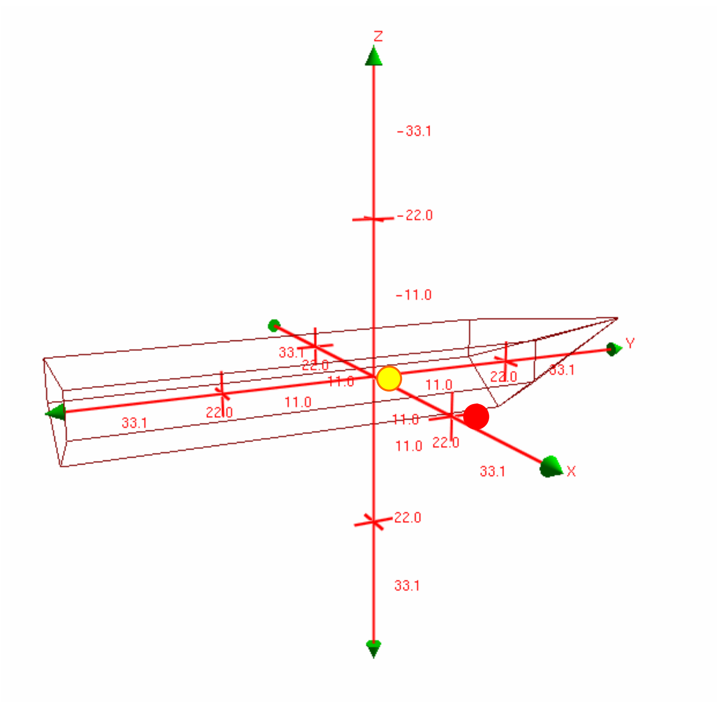


Figure 7. Schematic of locations of parts of the multibeam system. The red dot shows the location of the transducers (receive) and the yellow dot is the MRU. The navigation has been corrected to the MRU position and thus the offset is coincident with the MRU (yellow). The axes are placed on the approximate ship centre which is calculated from the values put in for length, beam and draught. These are not required in the calculations of multibeam bathymetry

The data was imported into HIPS from the raw archive format during the cruise into the Project file. The first task is to edit the data to remove spurious data. This can be divided into three specific areas: attitude data, navigation data and bathymetric data.

The attitude data generally has many spurious points. The weather during the entire cruise was variable. Pitching or rolling more than a couple of degrees were not experienced nor any ship heave of more than a few metres. It was therefore relatively straightforward to edit the data (graphically-see figure 8).

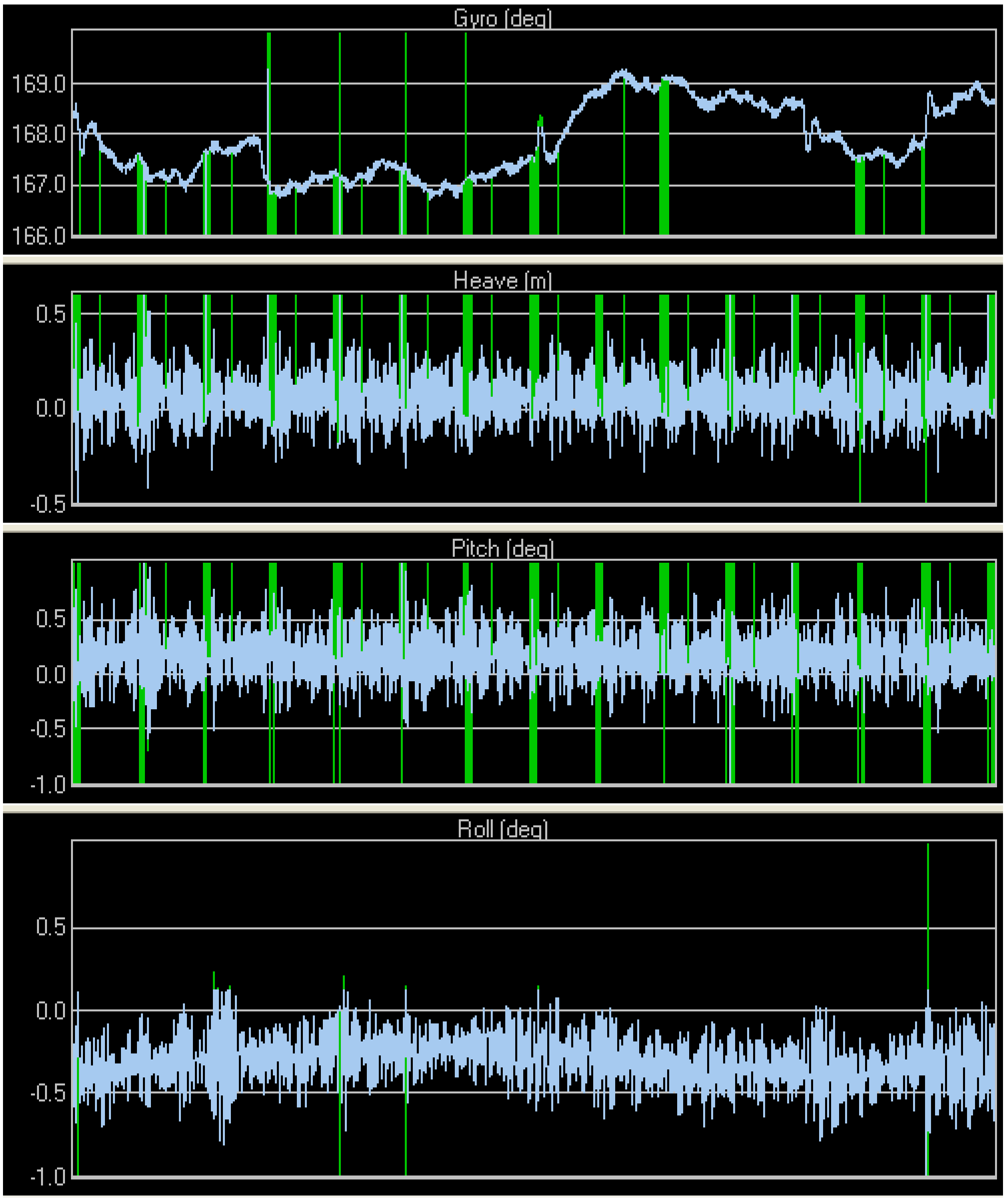


Figure 8. 4 Attitude graphs (Gyro, Heave, Pitch and Roll against time) for a piece of multibeam data (one hour). The edited (removed) values are shown in green

Without removal of these values the bathymetry data would be severely compromised. An automatic filter may have removed these spikes too but it was felt that manual editing was preferable as it was quick and more controllable. Typically one day of data in one hour sections would take about 10 minutes to edit by hand.

The navigation data is similarly edited for speed (between fixes), distance (between fixes) and course made good. Far fewer errors were encountered in these data. The course made good values appear to be noisy but are mainly due to the resolution of the DGPS fixes and the frequency of fixes (see Figure 9).

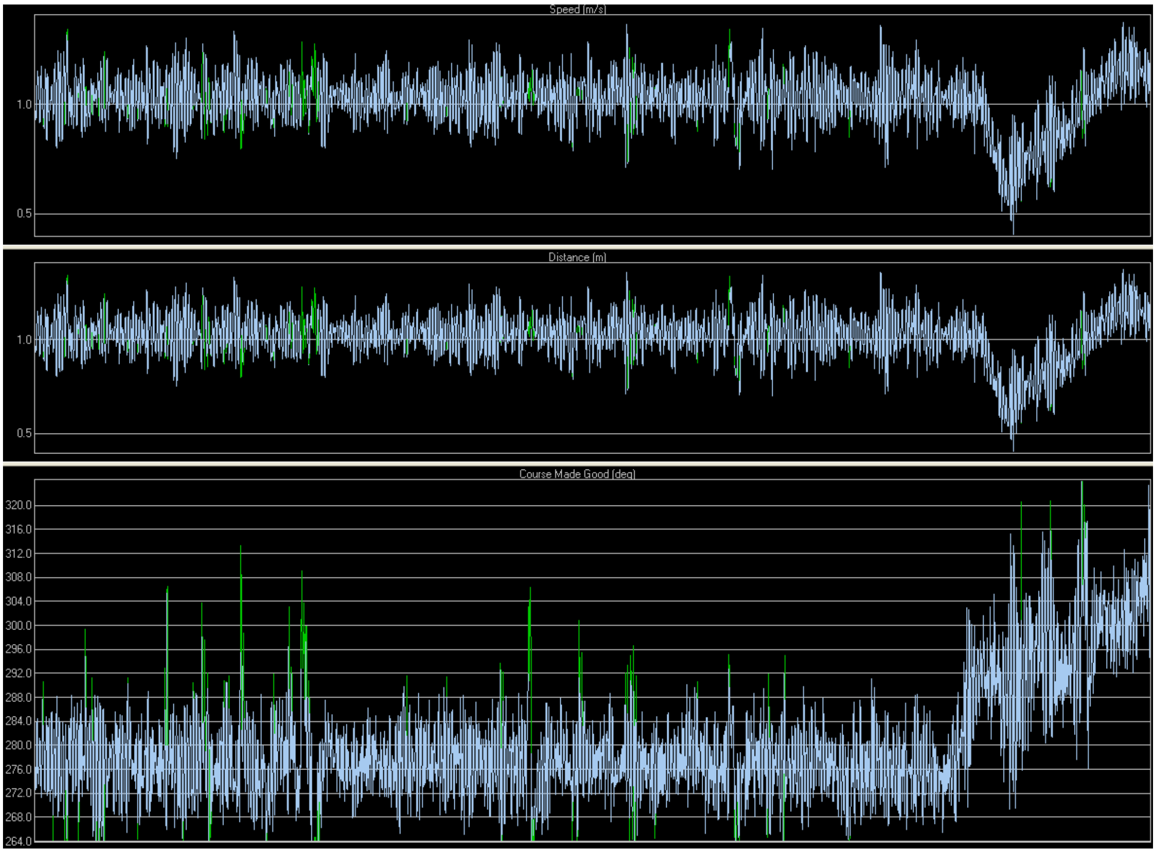
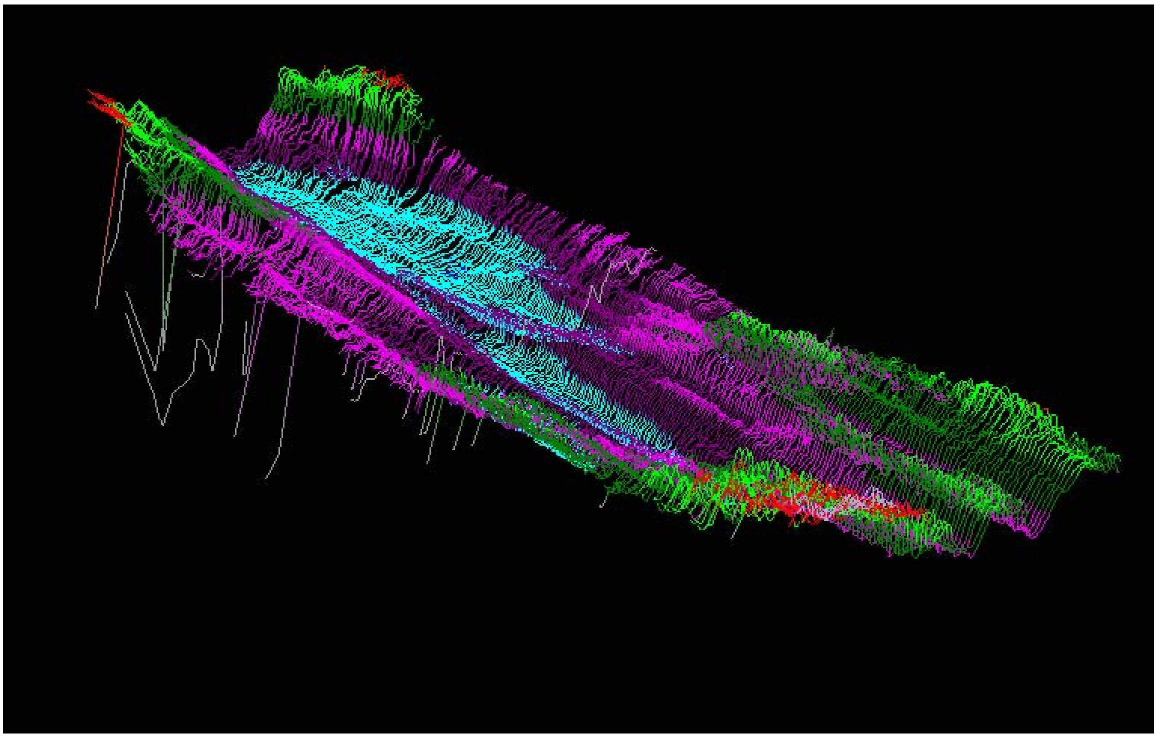


Figure 9   3 Navigational graphs (Speed, Distanceand course made good against time) for a piece of multibeam data (one hour). Again the edited (removed) values are shown in green.



Standard filtering for such bathymetry data would use a very mild to initially limit bathymetry data points. A filter could have been set to reject points between 200m and 5000m and any points from angles greater than 65° to nadir. Also single bathymetry points with less than 2 of its 4 neighbouring points could also have been also rejected. As the ship was generally moving slowly (2.5 kts) when towing TOBI or the ROV, the quality of bathymetric data was considered to be very good. Thus the automatic filtering stage was omitted and hand editing was carried out. The swath editor was used to edit the raw bathymetry values before geographic registration. The quickest and best method was found to be using the 3D editor which allows the user to view, rotate and edit the soundings (generally by removing them).

Zero tide was assumed for the survey data as no data was available and would probably fall into the error margin of the bathymetry values anyway. A couple of sound velocity profiles were taken during the survey. The profile (Figure 10) was used throughout the survey and showed no visible traces in the final bathymetry map of any misplacing positions or depths (taken via a XBT on 25th May 2008, 45° 20'N, 27° 52'W).

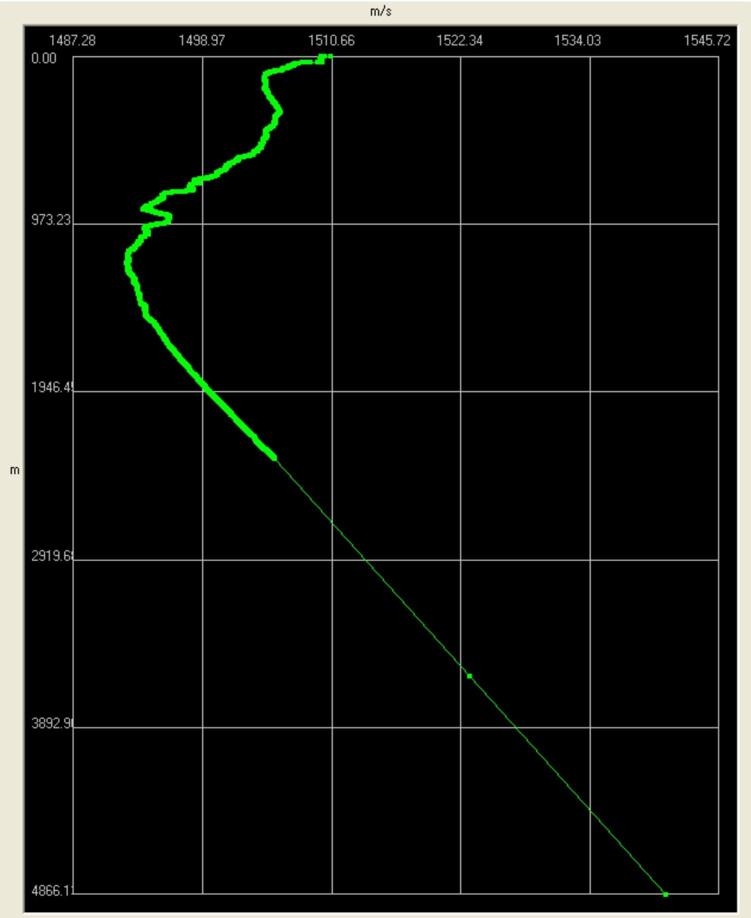


Figure 10. Sound velocity profile used during EM120 multibeam survey in CARIS processing. Actual data points are shown as green squares.

As no calibration patch test was performed the calibration results created at installation were used. These were:

Roll error = -0.07°

Pitch error = 0.01°

Gyro error = 0.01°

These are applied during geographic registration. Not all the bathymetry data lines were imported as much of their coverage was duplication of the main lines used to collect TOBI imagery. As the TOBI lines were run at relatively slow speed the quality of these data was assumed to be superior to further lines at very low speed (during ROV surveys) where ship heading was often not close to the track direction and covering the previously covered areas and therefore unnecessary. Many of the extra lines were generally collected during ROV and MAPR surveying. Removing these additional data speeded the data editing and processing.

After geographic registration on a UTM Zone 26 (WGS84) 50 metre grid the data was viewed in colour relief. The subset editor was used to identify the points where obvious problem bathymetry data were seen, and the points were removed. Generally the data only had errors at far range, or points were wildly in error. Figure 11 shows the rejected points in grey. The model can be rotated, tilted and zoomed in three dimensions and the offending points identified by a box or polygon. It shows all the soundings and not just the 50 metre grid which is created from the valid points using a search radius and weighting factor method integral to HIPS.

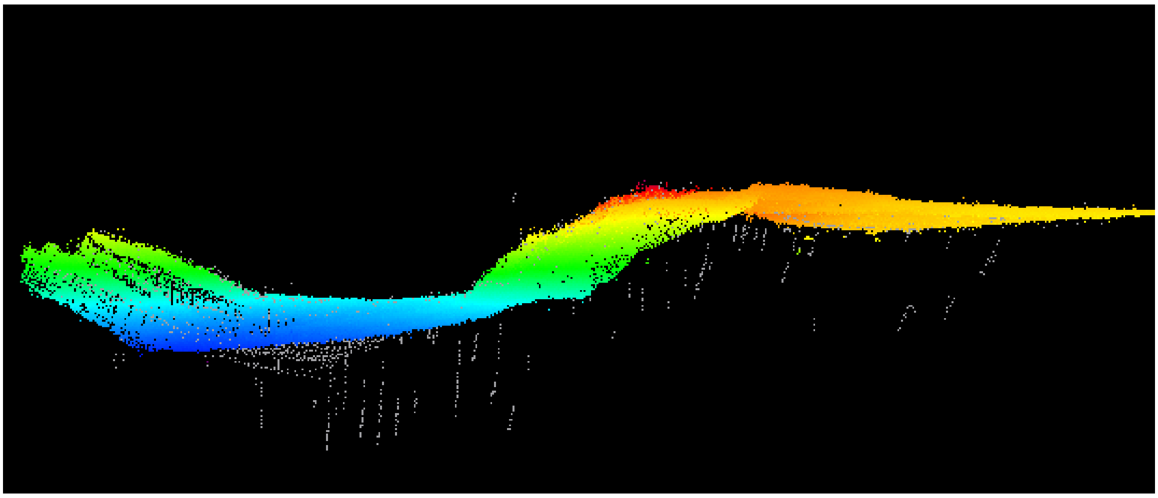


Figure 11. Example of subset editor in CARIS HIPS. The model can be rotated in 3D and points picked. Grey points are bad data points edited out.

The final mosaic can be output to an image or to ASCII XYZ. Imagery is of less use here as it has understanding of actual depths. Thus the grid was output to a data file in UTM metres and depth (both in metres).

Grids for software packages such as GMT and ERDAS Imgine version 9.1 were created. The depth values were multiplied by -1 to get proper topographic heights. Reprojection into other grid systems such as Mercator or Geographic coordinates is easy in ERDAS Imagine, and is conversion to common data format (e.g. GeoTiff).

B. Backscatter

The processing of Multibeam backscatter data is often forgotten or ignored. As a source of data that has already been collected, it seems illogical not to see whether the data has value. Initially the archive files are uncompressed and converted into their individual files using the Simrad Neptune software system “Replay”. For example a file 0208 such as:

```
  Date       Time        Size  Name

  31/05/2008 09:05        816
0208_20080531_090512_RRSJamesCook.ix2

  31/05/2008 09:05        120
0208_20080531_090512_RRSJamesCook.ix1

  31/05/2008 09:05 12,995,608
0208_20080531_090512_RRSJamesCook.all
```

converts to:

```
  Date       Time      Size   Name
31/05/2008 09:05  491300   0208_20080531_090512_00_01.depth
31/05/2008 09:05   18252   0208_20080531_090512_00_01.ind
31/05/2008 09:05    1308   0208_20080531_090512_00_01.para
31/05/2008 09:05   58124   0208_20080531_090512_00_01.pos
31/05/2008 09:05    2732   0208_20080531_090512_00_01.sfsvp
31/05/2008 09:05 2241188   0208_20080531_090512_00_01.sidescan
31/05/2008 09:05   58124   0208_20080531_090512_01_01.pos
31/05/2008 09:05   58124   0208_20080531_090512_03_01.pos
31/05/2008 09:05   17859   0208_20080531_090512.linestat
31/05/2008 09:05     663   0208_20080531_090512.plotstat
31/05/2008 09:50      60   adm.blocks
31/05/2008 09:50     105   adm.data
31/05/2008 09:50     332   current.line
31/05/2008 09:50  222984   line.sensors
31/05/2008 09:50       4   projection.data
31/05/2008 09:50   67400   survey.lines
31/05/2008 09:50   16640   TestLane.errTele
31/05/2008 09:50     191   uncertainty.param
```

These latter 8 files are updated by subsequent conversions but are required for processing. All these processed ("proc") files were then transferred to the PRISM Software system (Version 4.0). (LeBas, 2005).

The formats of these "proc" files are described in the EMx_IO library. Simrad has kindly lent the Linux version of the library files and thus the data could be decoded and raw data transferred to NetCDF format, similar to sidescan imagery. The processing proceeded in a similar way to the TOBI imagery (see later section). The configuration file for EM120 backscatter data that was used:

```
mrgnav -i %1 -o m1s2.mrgnav_1 -n ../nav/met74.nav -l 0,0
  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 -r res
```

To explain this in sonar terms (in order):

- Add the ships DGPS navigation to the imagery
- Low pass filter of the imagery taking a kernel of 1 by 21 pixels and filling zero pixels with an average value. Valid pixels have values between 130 and 255.
- High pass filter of the imagery taking a kernel of 1 by 301 pixels and filling zero pixels with an average value. Valid pixels have values between 130 and 255. The results are biased by adding 128
- Low pass filter of the imagery taking a kernel of 31 by 301 pixels and filling all valid pixels with the average value. Valid pixels have values between 130 and 255.
- Weighted combination of the high and low pass filters by addition of pixels and subtraction of 128.

  i.e. $X_{new} = 1 * (Average_{large\ area}) + 1 * (X_{old} - Average_{line} + 128) - 128$
- Restore the header information to the weighted combination file, as the filter process removes the sidescan information embedded in the NetCDF file
- Reduce the resolution of the imagery to the required value

The area was sufficiently small for all the area to be covered by one map. However as the tracklines are so close there is much overlap of the imagery. Unlike bathymetry data, the imagery cannot be averaged and thus mosaics must have insonification coherence (i.e. keeping the individual pieces of mosaic as big as possible). Thus 4 mosaics were created from different datafiles: north/south lines, east-west lines looking north, east-west lines looking south and the final extra lines in the area. These are summarised in the table.

Map No.	Min Long (W)	Max Long (W)	Min Lat (N)	Max Lat (N)	Datafiles
1	28º 3.132'	28º 37.938'	45º 17.106	45º 46.674'	70-92
1ewr	28º 3.132'	28º 37.938'	45º 17.106	45º 46.674'	93-147
1ews	28º 3.132'	28º 37.938'	45º 17.106	45º 46.674'	148-180
1extr	28º 3.132'	28º 37.938'	45º 17.106	45º 46.674'	181-208

Initial processing was done with a grid resolution of 20m . The resulting imagery seemed quite noisy. Further processing at 10m showed an equally noisy signature however averaging of pixels from 10m to 20m cleaned the imagery considerably (see Figure 12).

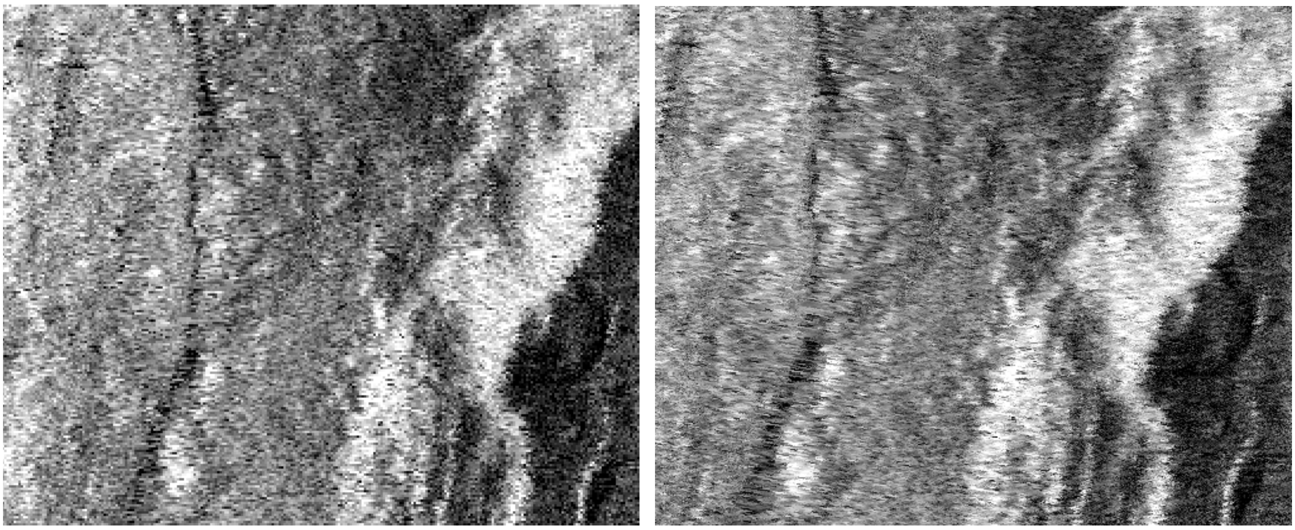


Figure 12. EM120 backscatter imagery processed at a resolution of 20m (left) and 10m (right) backscatter shown after pixel averaging. Imagery area shown is about 7 by 10km.

Pixel values of the EM120 backscatter imagery are calibrated to a dB scale in 0.5 dB steps. The conversion formula is :

$$\text{Backscatter (in dB)} = \frac{\text{(pixel value - 256)}}{2}$$

3) TOBI Sidescan sonar imagery

PRISM (Processing of Remotely-sensed Imagery for Seafloor Mapping) is a sonar software system that consists of several programs and processing scripts. The bulk of the programs were written by National Oceanography Centre Southampton (formerly the Southampton Oceanography Centre).

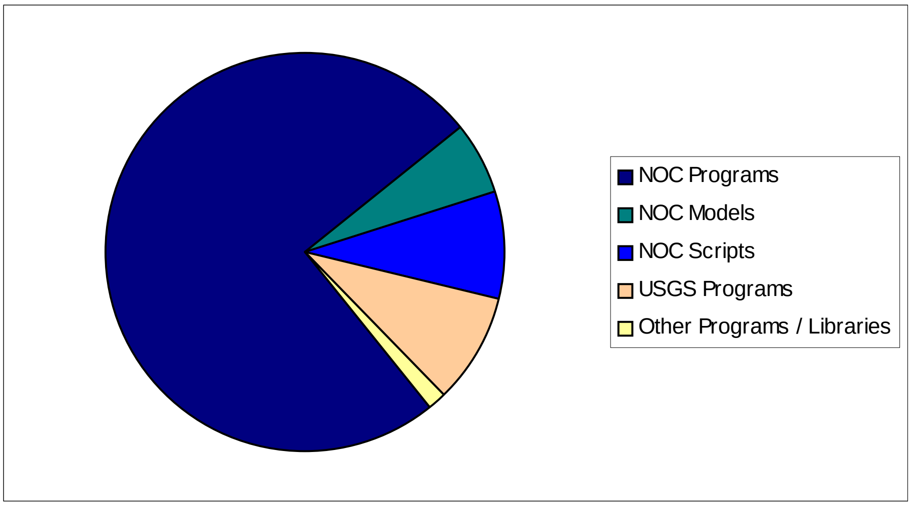


Figure 13. Pie Chart showing proportion of programs models and scripts in PRISM and their origin (mainly NOC)

The PRISM system constitutive programs are written mainly in C, and functions under a variety of UNIX environments (e.g. SOLRAIS & LINUX). NetCDF (Network Common Data Format) defines the basic imagery format. NetCDF is a self-describing network-transparent data format for data access provided by Unidata Program Centre. Unidata is a United States national program sponsored by the NSF, which is available to all academic communities at no cost. GMT and the MB system along with PRISM use the NetCDF format for input/output, which provides an additional degree of platform-independence. The University Corporation for Atmospheric Research holds copyright and all copyright notices are available with the PRISM source files.

The raw data was imported from CD-ROM into PRISM NetCDF. Initially the data was subsampled and averaged by 8 across-track, making pixel size 8ms or 6m. As survey speed was set to 2.5 knots (about 1.25 m/s), and mindful of TOBI's pulse repetition period of 4 seconds, the ping spacing is 5m along track. However as speeds reduced in practice during the survey to about 2 knots, it was decided to process the data at 3m resolution (subsample across track by a factor of 4). Interpolation of pixels along track at 3m resolution is required but is minimal. Le Bas and Huvenne (2007) show that maximum across-track resolution of TOBI is achieved by a subsample factor of 3 equating to 2.25m resolution but requires survey speed of 1.1 knots to prevent interpolation of pixels along-track.

Once the imagery is converted into NetCDF format for PRISM, the header information can be checked. This information has date, time, altitude of vehicle over the seafloor, gyro heading, roll, pitch, pressure, cable length and ship position. The most common error found in the data was the zeroing of pressure data. This occurred when the CTD snsor locked and had to be rebooted. Values for pressure were interpolated between known points of acceptable data. Data gaps where typically only a couple of minutes long (about 30 pings). No discernable artefact was visible in the imagery for these gaps and thus can be seen as corrections rather than interpolation.
Due to bad satellite coverage at one stage the TOBI clock reset itself but the data kept being recorded and thus corrections of times was easy. After about 30 minutes the GPS times were seen to be reliable and a new datafile started with correct times.

The configuration file used for the TOBI at 3m resolution was:

```
suppress_tobi -i %1 -o %0
mrgnav_inertia -i %1 -o %0 -u 202 -n navfile.veh_nav
renavtobi -i %1 -o %0 -n ../nav/renavmain.txt -v
tobtvg -i %1 -o %0 -l 10 # use gyro slightly smoothed
edge16 -i %1 -o %0 -m
pssinv -i %1 , ../bathy/area2.cdf -t -r res -o %0 -m ../bathy/map47.dat --
+proj=merc +ellps=WGS84 +lat_ts=0.0
median3 -i %1 -o %0
restorehdr_tobi -i %1 -h %3
batslr -i %4 , %2 -o %0 -r res -p
drpout -i %1 -o %0 -u -f -p -k 401
drpout -i %1 -o %0 -u -f -p -k 101
shade4_tobi -i %1 -o %0 -t1,4095 -n 1000
lookdirec -i %1 -o %0 -s 180.0
```

To explain this in sonar terms (in order):

- Removal of any surface reflection (i.e. from Vehicle to the sea surface and back) – generally only a problem in shallower water depths, where a bright stripe or line is seen semi-parallel to the ship's track. Removal is only done when the imagery is unambiguous, whether the line is true artefact and not actual seafloor feature. The result can sometimes be seen on the final imagery as a faint dark line.
- Merging of ship navigation and cable data with the imagery and calculation of the TOBI position using an inertial navigation algorithm. The 'navfile.veh_nav' file contains ship position and cable values and a umbilical length of 150 metre is assumed

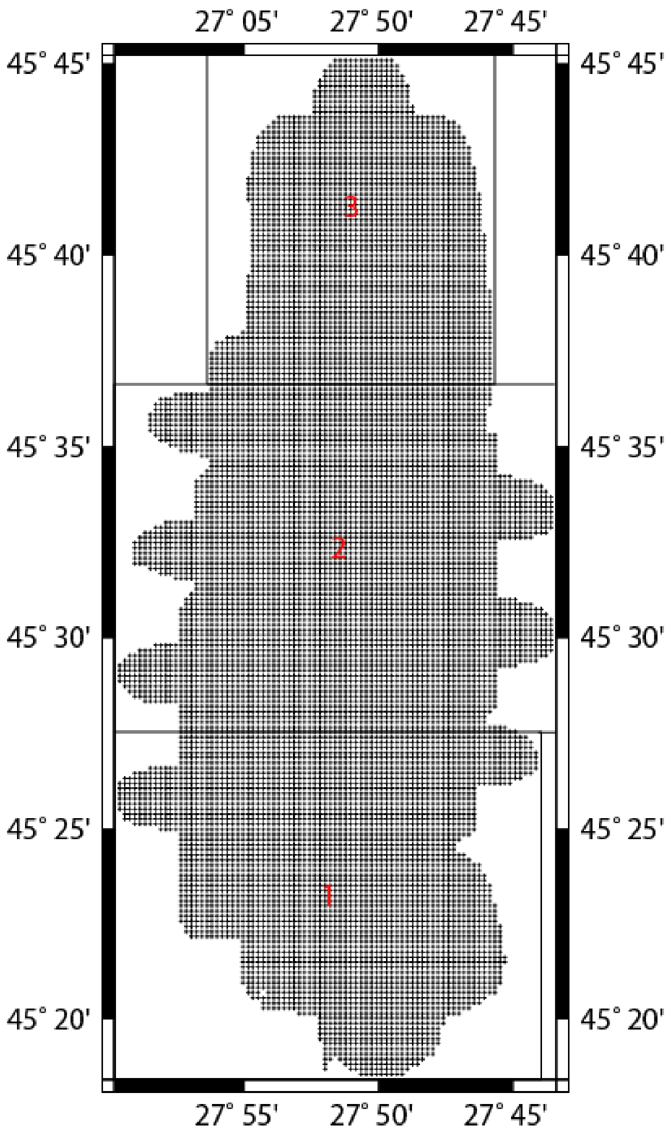
plus 52 metres from DGPS receiver to the stern. Various assumptions are applied: the cable is assumed to be straight, the cable value is assumed to be correct, zero cable is set when the depressor enters the water, and the umbilical length includes the distance between the GPS receiver and the point where the cable enters the water.

- The TOBI imagery was originally processed without this renavigation process. The first processing mosaics were then compared to the bathymetry data by hand and lateral offsets were measured and logged. The processing of a second processing mosaics then renavigated the TOBI track by pushing the vehicle sideways, assuming that ocean currents had pushed TOBI off the tack calculated by inertial navigation. This relies on features on the bathymetry to be recognisable and correlated to TOBI imagery features.
- Smoothing of the TOBI gyro values. A 10 ping smoothing filter is applied to the track heading values. The heading values are used in the geographic registration process to angle each ping relative to the TOBI position. Using the track heading, does not take account of any crabbing of the vehicle.
- Median filter to remove any high or bright speckle noise. A threshold is defined for the maximum deviation for adjoining pixels over a small area above which the pixel is replaced by a median value.
- Creation of a bathymetry datafile which corresponds to the coverage of the TOBI imagery (ping by ping). A Mercator map of the area must be available with the appropriate geographic limits. Mercator map created at 50m resolution from the EM120 bathymetry data collected concurrently on the cruise.
- Median filter the bathymetry data to remove any spikes that might be present in the original bathymetry data , kernel size 3 by 3 pixels.
- Reattach the header information to the bathymetry datafile
- True slant-range correction is calculated using the above corresponding bathymetry datafile and the TOBI imagery a and the TOBI imagery geometrically corrected. Each pixel is 4ms and equates to 3 metre resolution, any pixel gaps on the output file are filled by pixel replication.
- Dropout removal for large imagery dropouts. When the vehicle yaws excessively it is possible for the transmit and receive phase of each ping to be angled apart. If this exceeds the beam sensitivity value (0.8º) little or no signal is received, creating a dark line on the imagery. The program detects the dropout lines and interpolates new pixel values. If more than 7 dropouts are present concurrently (28 seconds) no interpolation is done.
- More dropout removal but for smaller, partial line dropouts. If more than 7 partial dropouts are present concurrently (28 seconds) no interpolation is done.
- Across-track equalisation of illumination on an equal angle basis. This assumes that the backscatter from a particular range should average a given amount for each piece of data. The near-range pixels and far-range pixels are generally darker than mid-range pixels. This is due to the transducer’s beam pattern and differences in seafloor backscatter response in terms of angle of incidence. The result of this is to amplify the near and far-range pixels by about 1.5 and reduce the mid-range pixels by 0.8. These values are calculated from the individual segment being processed. Values are normalised to a pixel value of 1000.
- Removal of data with a certain insonification direction. Value specifies the main direction of insonification to be kept (± 90º). The port or starboard imagery is set to zero and thus is not mosaicked. This process line was removed for the north-south lines (passes 1 to 4) as this mosaic did not have major amounts of overlap.

As the area was relatively small and the resolution high the survey was divided into 3 maps. Each map has about 7000 by 5500 pixels and data is 16 bit, thus filesizes are about 750Mb. Mercator projection was chosen with a standard latitude of 45º N. However as there was considerable overlap of the TOBI imagery it was decided to make 5 different mosaics for each area. The 5 different mosaics were

1. North –South lines
2. Sinuous East-West lines travelling northwards with insonification south looking
3. Sinuous East-West lines travelling northwards with insonification north looking
4. Sinuous East-West lines travelling southwards with insonification south looking
5. Sinuous East-West lines travelling southwards with insonification north looking

Thus 15 mosaics were created - The coordinates for the 15 areas were:



Map No.	Min Long (W)	Max Long (W)	Min Lat (N)	Max Lat (N)	Look Direction	Pass numbers
1	-27.997	-27.7325	45.3071	45.4567	Both	1-4

2	-27.997	-27.6975	45.4567	45.6063	Both	1-4
3	-27.9779	-27.6784	45.6063	45.7558	Both	1-4
11	-27.997	-27.7325	45.3071	45.4567	South	5-8
12	-27.997	-27.6975	45.4567	45.6063	South	5-8
13	-27.9779	-27.6784	45.6063	45.7558	South	5-8
16	-27.997	-27.7325	45.3071	45.4567	North	5-8
17	-27.997	-27.6975	45.4567	45.6063	North	5-8
18	-27.9779	-27.6784	45.6063	45.7558	North	5-8
21	-27.997	-27.7325	45.3071	45.4567	South	9-12
22	-27.997	-27.6975	45.4567	45.6063	South	9-12
23	-27.9779	-27.6784	45.6063	45.7558	South	9-12
26	-27.997	-27.7325	45.3071	45.4567	North	9-12
27	-27.997	-27.6975	45.4567	45.6063	North	9-12
28	-27.9779	-27.6784	45.6063	45.7558	North	9-12

The user has to decide where to trim overlapping imagery. Some features may be better insonified on one segment than the other (e.g. shadows) and thus can be cut around. The layers are then overlaid and a single mosaic image created. The stencilling and overlaying of layers was done the commercial software package ERDAS Imagine (version 9.1). This package has been customised to include PRISM functionality and formats. ERDAS Imagine is a powerful image processing and GIS software package and allows much image manipulation and map production. Reprojection to other coordinate systems is possible, as well as exports to other formats such as GeoTiff or ASCII xyz. The main .img format is also compatible with the Arc/Info GIS.

4) MS2000 Bathymetry (from ISIS ROV)

The raw MS2000 bathymetry data is logged onto a series of .smb format files. These are binary datafiles and contain the complete echogram for each ping (see Figure 14). Each file has a preset maximum size of 50Mb. Extension files to the original .smb file are given a numerical filetype which increments with each 50Mb of data. With a range of 200m set each 50Mb file is full after 75 seconds, thus the data rate can be seen to be very high.

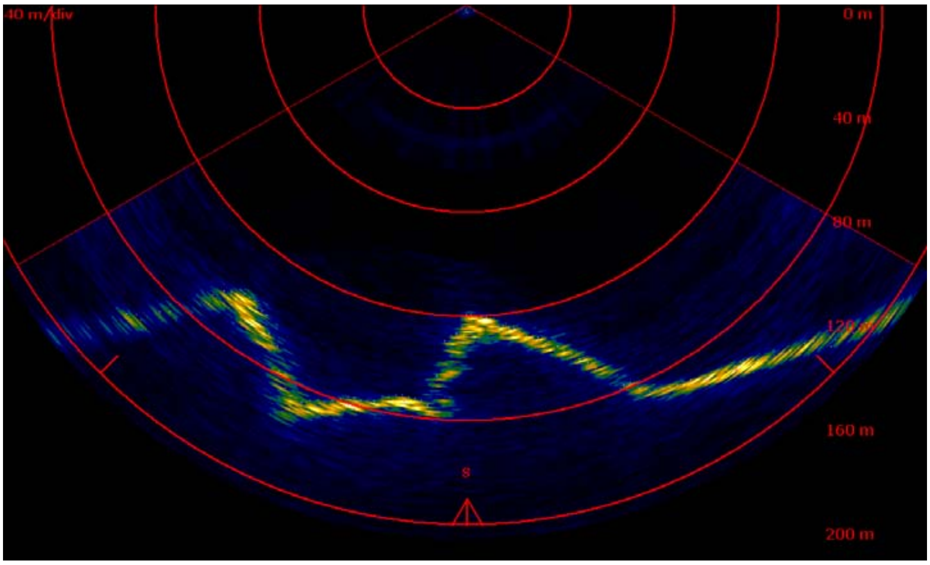


Figure 14. Echogram of the MS2000 showing one ping. This is stored in the .smb binary format.

During acquisition a bottom detection algorithm is run and if the thresholds are chosen well the resulting output can be exported to a .mab datafile. The name is composed of the start date and time of the data. This simply contains the beams number, time and depth values for the 128 beams for 744 pings (just over 12 minutes). These files are considerably smaller the .smb files but are also divided into extension files with numerical file types but keeping the filename the same. For instance:

Filename (Date and time of start)	Date of fileclose	Time of fileclose	Size (bytes)
Jun14,2008,08-51-09.mab	14/06/2008	09:03	405,520
Jun14,2008,08-51-09.e001	14/06/2008	09:16	405,520
Jun14,2008,08-51-09.e002	14/06/2008	09:28	405,520
Jun14,2008,08-51-09.e003	14/06/2008	09:40	405,520
Jun14,2008,08-51-09.e004	14/06/2008	09:53	405,520

To process the MS2000 data other data streams are required. These are the attitude, depth and position of the ROV. These are logged by the Techsas system and are stored separately. The format of these data can vary but generally have the same root filename. For processing in CARAIBES it is recommended to get the data in NetCDF format, though it is available in ASCII too if required. An example of the datafiles required for the above .mab files are:

Filename	Size (bytes)	Data held	Used?
20080614-085028-CSVLA-csv01.cdf	1,170,816	Depth of ROV	✓
20080614-085028-ISISdepth-Depth.pressure	333,908	depth	
20080614-085028-ISISwinch-	721,340	Cable	

winch01.cdf		length to ROV	
20080614-085028-Tss2-oct01.cdf	6,563,648	"Octans" attitude	✓
20080614-085028-position-DVLGGA.gps	1,648,092	Doppler position	
20080614-085028-position-Isis_gga01.gps	720,944	USBL position	✓

Processing the data was done using the CARAIBES software suite (v3.4) which runs under the Linux operating system, and was created by IFREMER. Once installed the system provides a object-orientated environment where modular programs can be strung together to create a processing package.

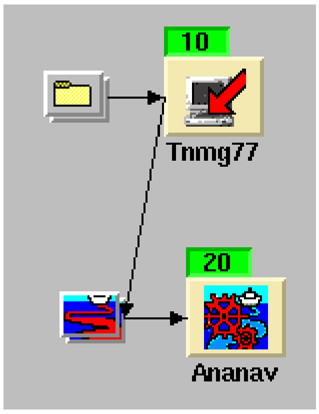
There are four processes (steps) that need to be addressed with the CARAIBES package:

1. Import and editing of the navigation for the ROV
2. Import of the 4 data sources and combination into a single bathymetry datafile which has all the necessary ping information (attitude, ROV depth and position)
3. Hand editing of the bathymetric data for removal of spurious points
4. Combination of bathymetry data into a DTM and export to XYZ datafile

Step 1 requires the navigation file for the ROV. As the USBL data was unusually good it was decided not to use the Doppler navigation datafile as that tended to drift and lose lock on the very uneven terrain. Thus the input file used was 200806xx-xxxxxx-position-Isis_gga01.gps. The editing of the navigation (using "Ananav") allowed removal of spurious points and the smoothing of values using a sliding mean over 10 samples. Gaps of over 60 seconds were not interpolated across. Output was to a similarly named file but with a different filetype extension 200806xx-xxxxxx-position-Isis_gga01.nvi.

<u>Input file</u>

200806xx-xxxxxx-position-Isis_gga01.gps



Step

Step 2 imports the attitude data, depth data and multibeam bathymetry depths and combines them. It then takes the navigation data created in Step 1 and creates a combined swath and header data. The process was also augmented by adding two very basic filters; one removing all data outside a regional threshold (specifically set here to depths less than 500m or more than 4000m), and one to remove any point that was more than 30m away from the mean of all depths within a geographical area of 10m square.

Input files

200806xx-xxxxxx-Tss2-oct01.cdf

Junxx,2008,xx-xx-xx.mab

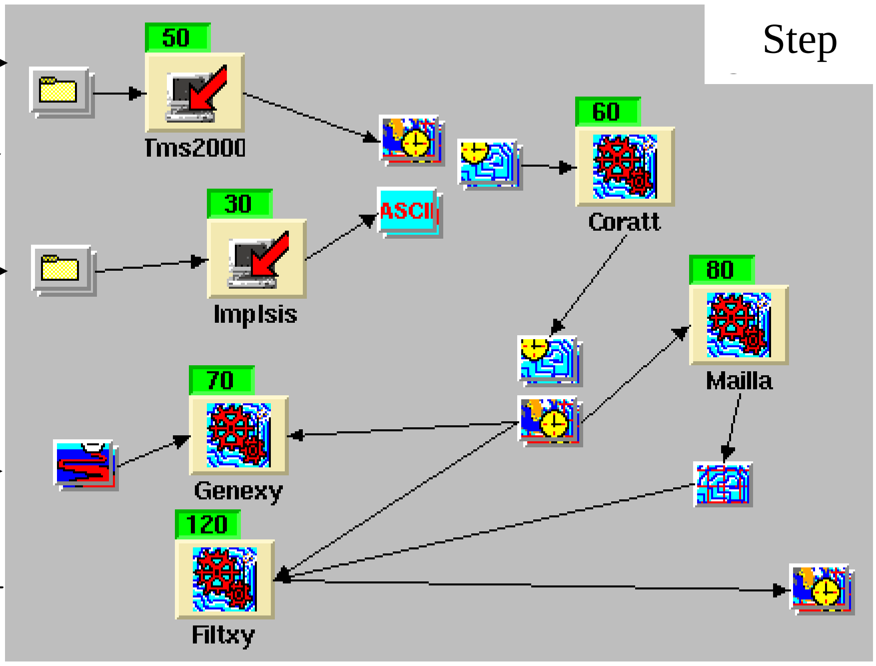
Junxx,2008,xx-xx-xx.e001

.

.

.

200806xx-xxxxxx-CSVLA-csv01.cdf

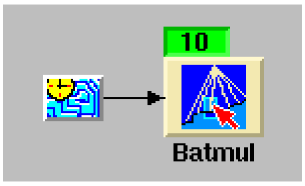


Step

Step 3 is the time-consuming step of hand editing the bathymetry file. Data spikes can be identified either in the beam cross-section, ping cross-section or in plan view

Input files

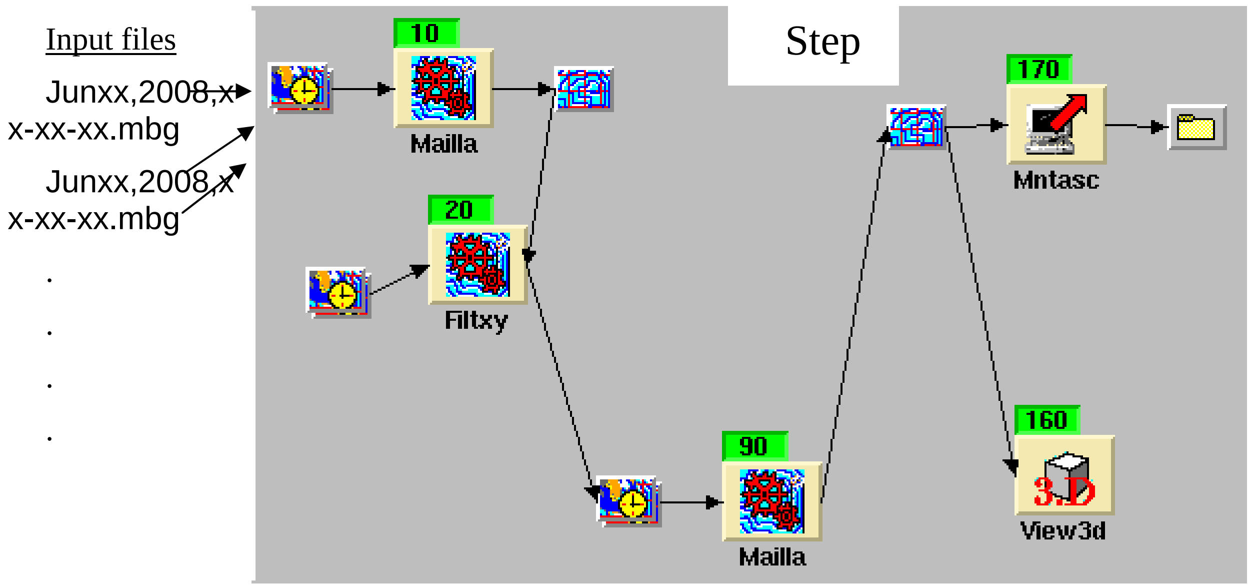
Junxx,2008,xx-xx-xx.mbg



Step

Steps 1 to 3 have to run many times, each time changing the input files pertinent to each line. At the end of these steps the user should have a series of .mbg files

Step 4 combines all the .mbg lines of a survey together into a single DTM. It initially creates a 10 metre resolution DTM from all the lines of data which averages many of the soundings together and produces a very smoothed surface. The input files are then combined again at a 2 metre resolution DTM but only using those depth values which are within 30 metres (vertical depth) of the smoothed 10m resolution surface. The data is output in two forms: a CARAIBES dtm to be viewed in the 3Dviewer, and as an ASCII xyz datafile (latitude, longitude and depth)



The xyz datafile was then imported into GMT and ERDAS imagine (via xyz2grd and grd2img respectfully).

Callibration of the MS2000 data for time latency, pitch and roll was done using two reciprocal lines of data. Comparing data collected in different directions allows a calibration of the transducer mounting on the ROV with respect to the attitude sensor. The positions of all the components on the ROV were measured whilst onboard earlier and these values were entered into the system (in step 2). Great care was taken on these measurements, especially the sign and coordinate conventions. These were:

On ISIS:

	X (m)	Y (m)	Z (bottom of ROV) (m)	Z (centre of ROV) (m)
MS2000 Rx	-0.66	0.45	-0.13	0.71
MS2000 Tx	-0.90	0.45	-0.03	0.81
Octans MRU	-1.92	-0.70	-0.60	0.24
Crossbow MRU	-1.80	0.60	-0.90	-0.06
USBL	-0.35	-1.00	-2.30	-1.46
Doppler Nav	-2.78	0.00	-0.47	0.37

Positive X is Forward

Positive Y is Starboard

Positive Z is Down

Whereas in CARAIBES:

	X (m)	Y (m)	Z (m)

Sounder	0.45	-0.66	0.71
GPS	0	0	0
VRU	-0.70	-1.92	0.24

Positive X is Starboard (Across)

Positive Y is Forward (Along)

Positive Z is Down

The position data (USBL or "GPS") has previously been corrected for offsets and thus in CARAIBES is set to zero.

Calibration of the multibeam system found that:

Pitch error = -0.5º

Roll error = -0.5º

Time Latency = 1.3 secs

Later in the cruise it was noticed that some of the attitude data was not being corrected well and it was found that a corruption in the original .mab file time code made the ping order unstable with spurious times and missing pings. CARAIBES seems not to be able to cope with these data errors and correction of attitude in times after these corruption points was haphazard and often resulting in being out of phase with the collected data. At present time of writing it is not known whether the corruption is due to the original acquisition system or the export process that creates the .mab files. Rerunning the export on the .smb files should provide an answer.

	MS2000 data	No. of extensions	Techsas data root filename
1	Jun13,2008,08-47-38.mab	6	20080613-084817
1	Jun13,2008,10-11-29.mab	0	20080613-084817
1	Jun13,2008,10-17-19.mab	19	20080613-084817
1	Jun13,2008,14-15-51.mab	10	20080613-084817
2	Jun13,2008,16-30-10.mab	1	20080613-162943
3	Jun13,2008,16-53-08.mab	36	20080613-165232
4	Jun14,2008,00-27-10.mab	2	20080614-002751
5	Jun14,2008,00-59-48.mab	36	20080614-005941
6	Jun14,2008,08-29-09.mab	1	20080614-082811
7	Jun14,2008,08-51-09.mab	15	20080614-085028
7	Jun14,2008,12-11-40.mab	20	20080614-085028

8	Jun14,2008,16-26-13.mab	1	20080614-162601
9	Jun14,2008,16-48-47.mab	2	20080614-164838

Dive 91 Line No.	MS2000 data	No. of extensions	Techsas data root filename
1	Jun17,2008,21-13-12.mab	15	20080617-210958
2	Jun18,2008,00-32-20.mab	1	20080618-003414
3	Jun18,2008,00-48-56.mab	14	20080618-005014
4	Jun18,2008,03-46-49.mab	0	20080618-034952
5	Jun18,2008,04-06-06.mab	1	20080618-040733
5	Jun18,2008,04-06-59.mab	13	20080618-040733
6	Jun18,2008,06-52-08.mab	1	20080618-065302
7	Jun18,2008,07-10-03.mab	14	20080618-071023
8	Jun18,2008,10-05-19.mab	1	20080618-100428
9	Jun18,2008,10-20-27.mab	13	20080618-101938
10	Jun18,2008,13-05-58.mab	2	20080618-130638
11	Jun18,2008,13-34-22.mab	0	20080618-133456
11	Jun18,2008,13-37-22.mab	0	20080618-133456
11	Jun18,2008,13-38-31.mab	0	20080618-133456
11	Jun18,2008,13-40-20.mab	0	20080618-133456
11	Jun18,2008,13-45-17.mab	12	20080618-133456
12	Jun18,2008,16-28-52.mab	2	20080618-162923
13	Jun18,2008,16-55-15.mab	12	20080618-165531
14	Jun18,2008,19-24-56.mab	1	20080618-192516
15	Jun18,2008,19-41-45.mab	12	20080618-194213
16	Jun18,2008,22-19-53.mab	1	20080618-221910
17	Jun18,2008,22-39-34.mab	12	20080618-223900
18	Jun19,2008,01-10-04.mab	1	20080619-011027
19	Jun19,2008,01-29-31.mab	11	20080619-012953
20	Jun19,2008,03-54-54.mab	1	20080619-035520
21	Jun19,2008,04-13-06.mab	11	20080619-041333
22	Jun19,2008,06-33-06.mab	1	20080619-063333
23	Jun19,2008,06-47-46.mab	5	20080619-064815

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TOBI Phase Bathymetry

K. Achenbach

TOBI is equipped to collect phase bathymetry data. These data are acquired by comparing the difference in phase at slightly offset pairs of transducers on the port and starboard side of TOBI. This phase difference allows for the calculation of the angle of reflection, and the time delay gives the distance from TOBI. This information can be combined to determine a bathymetric profile from returns along a single ping, and thus generates a swath with successive pings. Data are collected from two pairs of transducers mounted on TOBI—one on the starboard side and one on the port side. These transducers receive signals of 30.37 and 32.15 kHz, respectively. Theoretically, TOBI phase bathymetry should have approximately the same resolution as TOBI sidescan data (~5m/pixel), although in practice the phase data tend to be noisy and some resolution is lost to smoothing during processing.

During cruise JC24, phase bathymetry data were collected throughout the TOBI survey. Coverage of the study area should thus be quite dense, as the TOBI lines have considerable overlap (see chapter on TOBI sidescan). Phase data acquisition began at the start of the TOBI survey at approximately 13:45 GMT on Julian Day 146, and ceased at the end of the survey at approximately 23:45 on Julian Day 152. During the initial few hours of the survey, the transducer on the port side was malfunctioning, and returned data with a considerable amount of noise (Figure 15a). However, at approximately 22:15 on Julian Day 146, the problem appeared to correct itself. Subsequent data from both transducers was of very high quality (Figure 15b).

Shipboard processing of the TOBI phase bathymetry proved to be difficult. Processing software available onboard included MATLAB® code written by Mike Avgerinos and Jenny Morgan (both formerly of the University of Leeds). Unfortunately software version compatibility issues prevented the effective use of these programs, and processing will continue post-cruise.

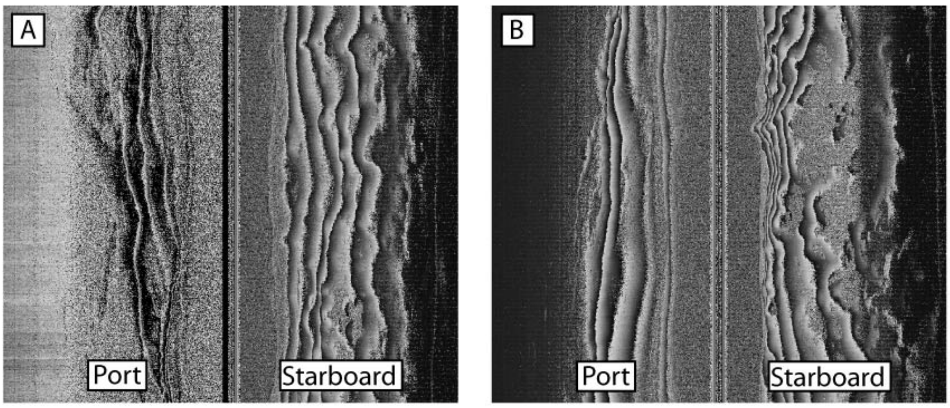

Figure 15: Example of TOBI phase bathymetry data. A) Data with malfunctioning port transducer. B) Data with functioning port transducer.

TOBI Magnetic processing

Maurice Tivey

Magnetic data were obtained as digital ascii comma separated value (CSV) files from the optical disk data recordings. The magnetometer values had already been converted to the appropriate units (nanoTesla) by the acquisition system. An example header line and basic data are arranged as follows:

```
   Year,Month,Day,Hours,Mins,Secs,Lat Deg,Lat Mins,Lon Deg,Lon
Mins,MagX(nT),MagY(nT),MagZ(nT),Mag
Tot(nT),Pitch(Deg.),Roll(Deg.),Gyro(Deg.),Conductivity(mmho),Temp(deg
C),Depth(m),LSS(Volts)

   2008, 5,26, 4,18,46,45,41.869999,-27,-48.439999,8509,-
5936,44704,45893,11.6,1.7,156.3,32.8600,3.5930,2013.6,0.17628670
```

The CSV data were loaded into MATLAB and saved as a struct array for calibration and processing. These data include the timestamp, magnetic component data (X,Y,Z), vehicle attitude information (pitch, roll, gyro heading, depth) and ship position in latitude and longitude. The magnetometer sensor is not an absolute field measuring device and thus needs to be calibrated relative to the local regional field for the permanent and induced field effects of the TOBI vehicle. The TOBI attitude sensors and gyro heading are used in the calibration. At the beginning of the survey TOBI did a calibration circle of radius about 1 km at a water depth of 500 m (Fig. 16). The vector sum of the three-components (the Total Field) should not change during this spin, however, the permanent field of the vehicle and any induced field effects will offset the field components and produce a ripple or undulation in the Total Field intensity as TOBI rotates. It was found that pitch and roll needed to be both changed in sign in order to correspond to a left-handed magnetic coordinate system of North, East and down as positive.

We used the full-vector calibration method of Isezaki, (1985) as modified by Korenaga, (1995) which uses the attitude data (heading, pitch and roll) provided by TOBI tilt and gyro sensors to correct all three magnetic field components for the motion of the vehicle and compare with a predicted field variation. We estimate the magnitude of the predicted field components using the most recent International Geomagnetic Reference field model (e.g. IGRF2005) for the location and date of the survey. The calibration code is written as a set of MATLAB scripts (Maurice Tivey) that process the calibration turn data to obtain a coefficient matrix. This calibrationmatrix is then applied to the entire data set. TOBI produces a permanent magnetic field effect on the order of 3000 nT during a calibration spin (Fig. 17). This field variation is reduced by a factor of ten.

```
   TOBI Calibration - JC24 Disk Record 2010
   Latitude/Longitude      45.3373333     -27.8671667
   Latitude/Longitude (deg min):   45    20.24  -27   -52.03
   Indices: 708 2096

    Offset between raw observed and predicted field:
```

```
 X-component Mean diff:  7264.51 nT   RMS diff:  3248.38
 Y-component Mean diff:  9001.60 nT   RMS diff:  5356.86
 Z-component Mean diff:   793.22 nT   RMS diff:   477.94

 Offset between corrected and predicted field:
 X-component Mean diff:   299.99 nT   RMS diff:   262.08
 Y-component Mean diff:   426.94 nT   RMS diff:   298.10
 Z-component Mean diff:   149.54 nT   RMS diff:   140.41
 Total Field Mean diff:    79.89 nT   RMS diff:    64.74

 Calibration Coefficient Matrix
   0.89229    0.41558   -0.15033   2647.13
  -0.45145    0.86996   -0.14554   3929.94
   0.00978    0.02661    0.96891   1928.97

Field Parameters: (IGRF 2005)
Latitude/Longitude (dec deg):      45.3373333     -27.8671667
Latitude/Longitude (deg min):   45    20.24  -27   -52.03
Average Magnetic Inclination 61.510 degrees
Average Magnetic Declination -11.556 degrees
IGRF Magnetic Inclination 61.512 degrees
IGRF Magnetic Declination -11.705 degrees

Average X-component 21973.19 nT
Average Y-component -4492.32 nT
Average Z-component 41335.98 nT
 IGRF X-component 21964.56 nT
 IGRF Y-component -4550.77 nT
 IGRF Z-component 41334.12 nT

Original Total Field variation:  3133.00 nT
```

Initial Magnetic Analysis

The calibration coefficient matrix is applied to the entire TOBI data set and the results saved in a MATLAB binary file. The magnetic data were then merged with the cleaned and smoothed TOBI navigation data obtained from the sidescan processing to produce a complete time indexed and spatially indexed array of data points in MATLAB format. Figure 18 shows a plot the observed east-west oriented total field magnetic anomaly profile data from north to south. The two north-south oriented lines are essentially tie lines and don’t show any interesting magnetic structure as expected. The individual profiles can be extracted, continued upward to a level plane and inverted assuming two dimensional sources, however, for a quick look at the data they were also output to ASCII xyz files of corrected total magnetic field data and TOBI depth in lat, long coordinates for eventual interpolation into a grid format:

```
jc24tobi_tf.llz – total magnetic field (nT)
jc24tobi_fdp.llz – fish(TOBI) depth (m)
```

The International Geomagnetic reference Field (IGRF 2005) was removed from the measured magnetic data based on the position of the measurement to provide the total magnetic anomaly field value.

```
jc24tobi_anm.llz – magnetic anomaly field (nT)
```

These XYZ files were interpolated onto a grid using the GMT *surface* command which uses a minimum curvature algorithm and produces a fully populated grid of points. A fully populated grid is needed for the Fast Fourier Transform analysis. The *nearneighbor* GMT command was also used to create a masked grid restricted to where data actually exists. A grid spacing of 1 arc second equivalent to approx. 30 m was employed. The processed EM120 bathymetry was resampled to match the magnetic grid spacing for seafloor depth. Three GMT format grids are produced:

```
jc24tobi_bth.grd  - bathymetry (m)
jc24tobi_fdp.grd -  fish (TOBI) depth (m)
jc24tobi_anm.grd  - observed total field intensity (nT)
```

The total magnetic field data grid is continued upward to a level plane (-2 km level) above the topography using an iterative Fourier transform method (see Guspi, 1987). The resultant upward continued field is saved as a GMT format grid:

```
jc24tobi_gup.grd -  upward continued total magnetic field (nT)
```

The upward continued field is then used along with the bathymetry to compute a crustal magnetization using the Fourier Transform approach of Parker and Huestis (1974). This inversion removes the topographic effect from the magnetic field to compute a source magnetization. First, it is assumed the source of the magnetism resides in the underlying crust, which has a constant thickness (0.5 km) with the upper surface defined by the topography. The second assumption is that the direction of the magnetization vector is constant within the source layer (i.e. it doesn't vary with depth) and is parallel to the present day geocentric field direction computed from the IGRF 2005 (Inclination= +61.5, Declination=0).

The inversion magnetization solution has a zero-mean, which means it shows both positive and negative (reverse polarity) magnetization. However, because the TOBI survey is located well within the Brunhes normal polarity period over young ocean crust, the reverse magnetization simply means reduced magnetization and has no reverse polarity connotation. On a related point, the magnetization solution is a non-unique solution. A magnetization inversion solution exists that produces no external magnetic field. This solution is called the annihilator and in theory an infinite amount of annihilator can be added to the magnetization solution without any effect on the field. Typically, we add enough annihilator to the magnetization solution to DC-shift the magnetization solution to all positive values. This often has little to no effect on the shape and relative magnitude of anomalies that have been computed through the inversion process. Thus, for most applications the magnetization values should be read as relative to the lowest value. The following GMT format grids are created:

jc24tobi_mag.grd - computed crustal magnetization (A/m)

jc24tobi_mag_mask.grd - masked crustal magnetization (A/m)

Remaining analysis of the TOBI data will focus on improving resolution of the magnetic inversion results by inverting the individual lines which have less interpolation filtering than the gridded data set. The vector data will also be used to determine the strike of the magnetic contacts (Seama et al., 1993) and may also be used to compute horizontal gradient data to enhance interpolation of the gridded data set. The magnetic data will ultimately be interpreted in context with the geologic observations and age data from the sample analysis.

Figures

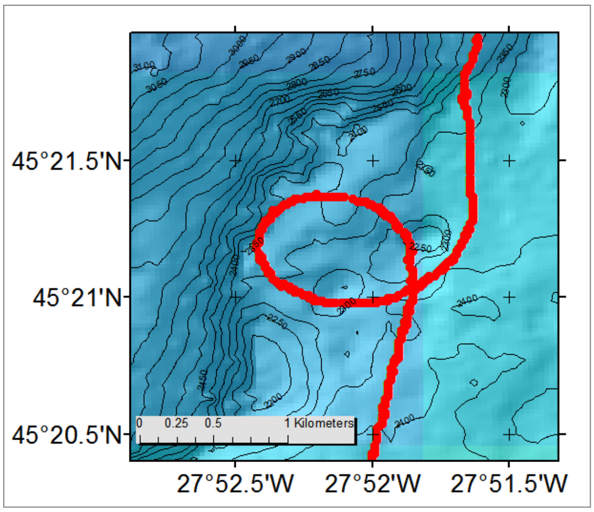

Figure 16. Map of TOBI calibration circle ship track conducted on the first day of operations.

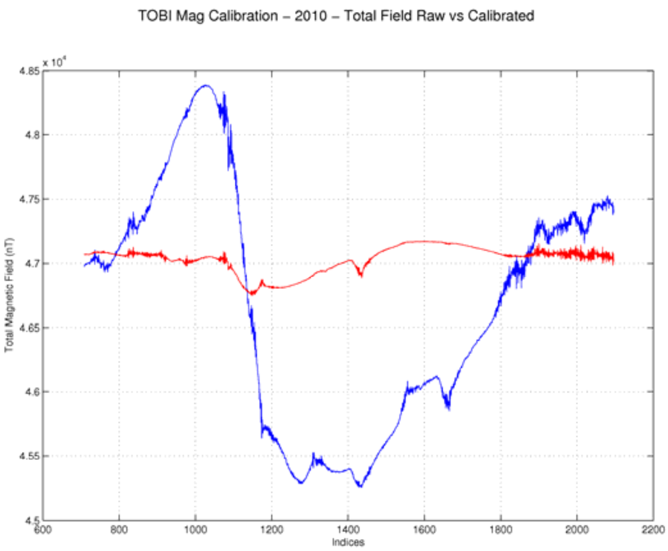

Figure 17. Plot of calibration turn observed total magnetic field data (blue) and the corrected total field data (red). A residual curve remains on the order of a few hundred nanoTesla but has relatively little effect on the data.

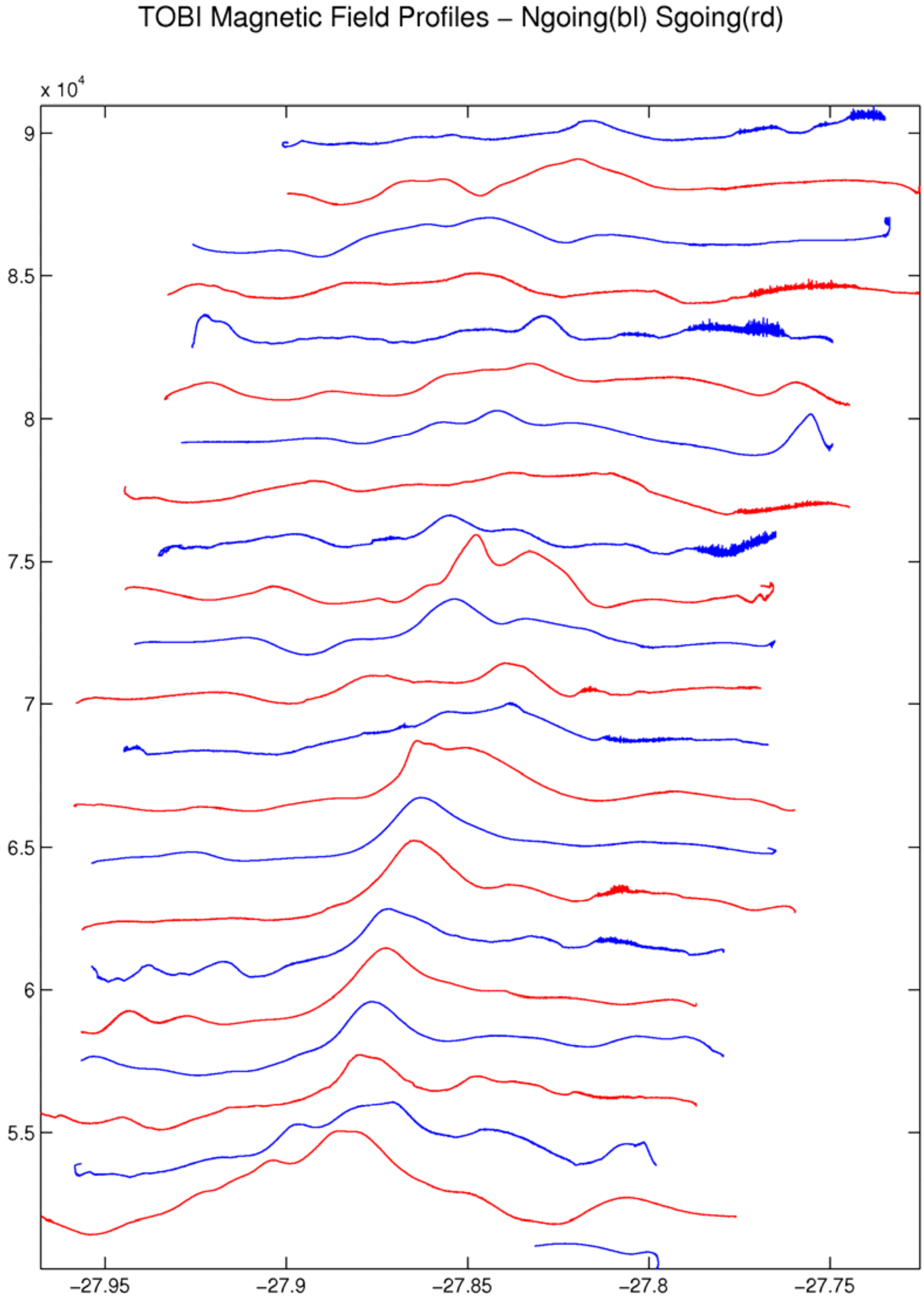

Figure 18. TOBI observed magnetic anomaly field profiles per trackline and stacked according to latitude position and plotted versus longitude . Blue profiles are north-going tracks, red profiles are south-going tracks.

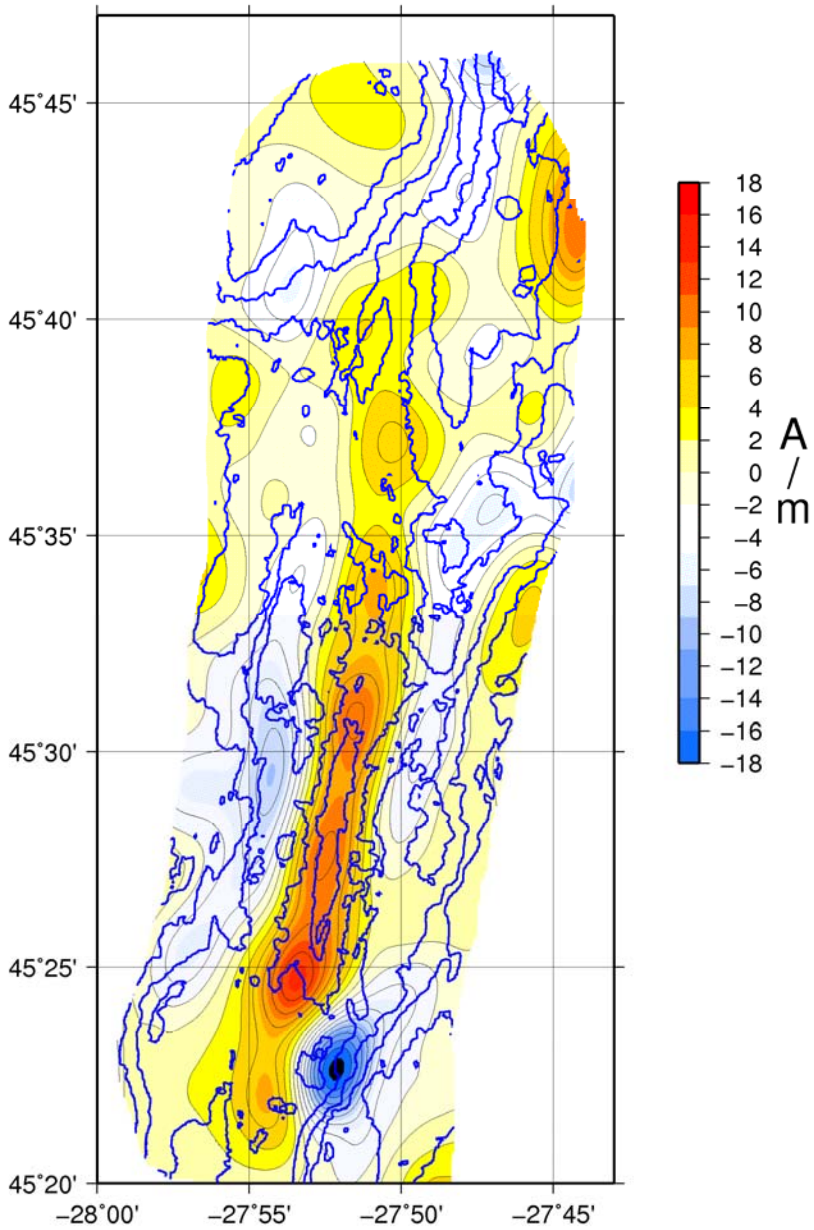

Figure 19. Crustal magnetization computed from TOBI magnetic data (2 A/m contours). Blue contours are EM120 bathymetry at 100 m interval..

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Seama, N., Y. Nogi, N. Isezaki, , A new method for precise determination of the position and strike of magnetic boundaries using vector data of the geomagnetic anomaly field, Geophys. J. Int., 113, 155-164, 1993

ISIS System

Dave Turner

Isis Statistics

No. of dives	16 (dive no. 79 to dive no.94)
Total run time for (JC024) thrusters:	364 hrs
Total time at seabed or survey depth:	311.5 hrs
Isis ROV *total* run time:	1635.5 hrs
Max Depth and Dive Durations:	3600m and 38 hrs
Max Dive Duration and Depth:	43 hrs and 3100m (dive 92)
Qty Swath Data:	~160GB
Qty Techsas Data:	~25GB
Qty DVR Video (4-ch, low frame rate)	~900GB
Qty DV Cam tapes:	360
Qty DVDs:	270

1. Mobilisation:

The majority of the Isis system was loaded onto the ship in Caldera, from where it had been stored from the previous cruise.

The two control containers and the LARS had remained onboard from the previous cruise, and only required their electrical and hydraulic connections. It was noted that the expanding foam seal between the two containers had been disturbed from the installation of other containers being stacked on top. This consequently meant that some water had leaked into the control space. No damage was reported and the foam was sealed temporally using duct tape. A more permanent solution to this join is required.

The installation of the bedplate, winch, storage drum, and the two deck containers went well, with the system powered up within the day. The Isis vehicle was unloaded from its container on the quay wall, with the aid of a forklift, pulling it out. The vehicle was then lifted directly into its deployment position within the LARS.

Some time was lost during the following day when the LARS docking head refused to operate all of its functions, ‘swing, and full ‘tilt’. This was later traced to a bad connection into the deck consol from the HPU. Unfortunately a few hrs was spent checking connectors, which appeared ok, wires and circuits before the fault was traced.

During the steam from Caldera to Panama the Isis system was bought on line, completing the umbilical termination and connection to the vehicle. During initial power up and vehicle checks it was noted that one of the thrusters was not operational. This was traced to one of the motor drive control modules, which once replaced operated without any further problems.

The vehicle and system was left fully operational, ready for the cruise to start a week later from the Azores.

2. De-Mobilisation

All NMFD systems have been dismantled, packed and made ready for lifting ashore on arrival in Southampton, UK.

3. Isis Handling System:

3.1 Hydraulic Power Unit (HPU):

This worked well for the duration of the cruise.

3.2 Storage Drum/ Traction Winch:

The Traction winch worked well for the duration of the cruise.

The Storage Drum encountered a problem just after Dive 86 whereby the drive sprocket of the storage winch started to slip. The dive was aborted, and the motor/ drive assembly stripped for inspection. The drive sprocket was found to be badly worn, and the roller chain seized in places. Some wear of the drive sprocket had been noticed during routine greasing of the drive chain, however it was not anticipated that the sprocket would further deteriorate as rapidly as it did.

Due to the severity of the sprocket wear it was deemed that the system would not be operable until a replacement sprocket and chain were put in place.

A replacement sprocket and roller chain was quickly sourced. At this point the ship set sail for the Azores, and on arrival (11^{th} June) spare components were waiting. The new parts were fitted, and the winch system pull tested as part of a re termination test. The condition of the chain drive mechanism was closely monitored for the remainder of the cruise. The chain was re tensioned after two dives.

Due to the four day turn around to and from the Azores, it was decided that this was a good time to re-terminate the cable, as would have happened mid cruise. The Storage drum had 20m of wire cropped off and was re-terminated and load tested to 7000kg. A further 100m of cable was removed at the end of the cruise when the termination was cut off. All details have been entered into the Umbilical log.

During the cruise the storage drum wire was cooled using a non toxic supply sprinkling water onto the wire. On the final dives the non toxic water supply was replaced with fresh water to give the wire a rinse.

Future modifications/recommendations/maintenance:

- The chain drive should be closely monitored as part of routine operational checks, maintenance intervals reduced, the chain and drive sprocket considered as a consumable item.
- Umbilical termination needs some design work and manufacture of a locking device to stop the termination rotating within the docking bullet.

3.3 Launch and Recovery System (LARS):

This worked well for the duration of the cruise, with no major problems encountered.

During the mobilisation we had a problem with the movement of the docking head assembly, this seemed to have limited movement in some of the axis, and appeared to run slowly. After several hours of fault finding we ended back at the connector that connects from the HPU to the deck control consol. During this process several wires in the docking head assembly were re-wired as they appeared not to be too sturdy. The connector was seated correctly after several attempts, and no further problems were encountered.

The tugger wheel assembly worked fairly well during most deployments and recoveries. On a few occasions the drive motor failed to engage, due to either an electrical or hydraulic signal failure.

The tugger wheel was replaced part way through the cruise as it had started to deteriorate. The bolts on the new tugger wheel were drilled and wired to prevent the regular occurrence of them coming loose

The Small hydraulic oil leak on the right side lower ram (looking outboard), has not gotten worse, and dose not appear to be leaking at present. This will be addressed during LARS DNV certification.

3.4 CCTV:

Two mini ‘bullet’ cams provide video feeds of the main winch and scrolling assembly. They are not suitable for use in a harsh marine environment, condensation often forming within the housing occluding vision. There are no suitable mounts provided on the camera units.

A low light splash proof camera is mounted for a view of the main launch and recovery system, again there are no suitable mounts provided and weather proofing of the unit is questionable.

The main pan and tilt CCTV camera, used to guide the pilot in launch and recovery operations, functioned as expected and is the only part of the system that can be mounted easily. A second fixed CCTV camera provides a fixed view over the port side of the ship, but again this requires suitable mechanical mounts to be fitted.

Although functional for the cruise an upgrade, specifically pertaining to the mechanical and environmental requirements of the system, is required. ‘BFS engineering’ Ltd is investigating a solution.

4. ISIS External Equipment:

4.1 Elevators

The Elevators were not used during JC24.

4.2 USBL & LBL Acoustic System (Sonardyne):

The ISIS Compatt5 USBL beacon has usually been fitted in Responder mode for all dives. However during the first dive the acoustic commands to turn the beacon into Responder mode failed, and tracking was continued in two-way acoustic mode without incident.

Upon recovery the beacon was set to Responder mode using the UM-8063 deck test unit and acoustic wand.

During the course of the cruise however there was discussion into procedures relating to the possibility of tracking should the ISIS ROV suffer a communication and/or power malfunction, requiring a dead vehicle recovery. If the Compatt5 was set to Responder mode and should a power outage/communication occur tracking would fail immediately, and acoustic commands would be needed to reinstate normal mode operations. Given this possibility the Compatt5 beacon was set to normal two way acoustic communication mode for the majority of the dive programme.

Compatt5 battery health was monitored during the cruise, and was found initially to have a 41% charge remaining (note, this differs to the value of 86% remaining charge measured at the end of JC021, the reason for which is yet unknown), and a 32% charge remaining at the end of JC024 operations.

Consultation with Sonardyne Ltd engineers confirmed that, even though the Compatt5 beacon is powered from the vehicle, battery power is used during ‘High power telemetry operations’. Further clarification from Sonardyne Ltd will be sought on return to base in order to define the most suitable procedure for Compatt5 configurations for future ISIS dives.

Tracking envelopes were similar to those described in the JC021 cruise report.

The control room side of the USBL system consisting of the Navigation control unit (NCU) and the Sonardyne PC performed as expected although it was noted that the Sonardyne PC would reboot itself sporadically resulting in a temporary loss of tracking. The reason for this is uncertain but it is suspected that the slow operation of the Sonardyne PC due to its age and limited performance is the cause, as well as time de-synchronisation issues. The large number of mission waypoints during this expedition also highlights the need for a definitive policy on assigning navigation/dive critical waypoints and scientific sampling waypoints on our system. It is recommended that only scientific waypoints of extreme interest be added to navigation computer job file during the course of a dive.

The position of the vehicle CRP was changed from the front of the tool tray to the centre, front bottom of the main vehicle structure, i.e. above the tool-tray. All offsets were changed to reflect this repositioning.

A folder C:\JC024 was created at the start of the cruise. The cruise job was created such that all relevant files including waypoints were recorded under this directory.

4.3 Football Floats:

These worked well for the duration of the cruise. However, one float was lost during a deployment. This float had not been secured properly, and when pushed over the side of the ship, fell off into the water. It was not possible to try and retrieve the float as all hands were fully engaged on the deployment of the ROV. By the time the ROV was secure and on its way down, the football float had drifted a long way off from the ship. Conditions were not suitable to launch the work boat.

5. Isis ROV:

5.1 Thrusters:

In order to find a solution to premature wear of thruster motor shafts the two vertical thrusters were fitted with the following during the mobilisation period:-

Port Vertical – Chrome plated shaft & standard seals.

Starboard Vertical – New standard shaft & trial seals.

There was no noticeable difference in the operation of the two vertical motors. The motors will be inspected for wear upon return to NOC.

The Port Horizontal Motor was replaced after completion of Dive 091 (17th June 2008) due to noisy bearings.

Thruster Controllers:

During mobilisation one of the thruster drive modules failed. This was addressed by replacing the thrusters pod with the spare one. Unfortunately the spare pod had a faulty module in it. The good module from each pod were installed in the original pod and the system now functions correctly. This has left the spares with just one good working thruster's module.

During the deduction process to determine the location of the failure, it was observed that the power directed to the two aft thrusters was reversed. The control circuits were ok.

5.2 Vehicle Main System Compensators:

During the mobilization period the main & transformer comps (Schilling 2 litre) were fitted with trial low pressure springs to give a maximum 3 psi positive pressure. Two of the existing springs were found to be broken. There was no noticeable improvement in comp oil duration as a result of the lower pressure springs having been fitted.

5.3 Tool Sled:

Drawer:

The drawer worked well for the duration of the cruise. However, there was one incident (dive 092) whereby the wire mesh below got pushed up, from the result of some hard landings on some rocky terrain, preventing the drawer from fully retracting.

Swing Arms:

The swing arm latches were generally ineffective. The latches failed to secure the swing arms during most dives and recoveries. The rotate motors lack power and fine control.

19-06-08 (dive 92) Port swing arm functioned on pre dive test, but failed to operate during the dive. The cause was found to be that the bolts had bent, allowing the arm to drop. This meant that the arm was now resting on the base of the tool tray preventing in from moving in any direction.

Deck Plates:

The two stbd rear deck plates were lost during a dive. This resulted in the loss of one lead ballast weight and the rovnav cable becoming detached. The cable was recovered the dive terminated. The deck plates under the drawer and port swing arm were badly damaged due to frequent landing on rough terrain. The smooth operation of the drawer was affected by the distorted deck plates.

5.4 Hydraulic System:

The hydraulic system worked well for the duration of the cruise.

The HP and water separator filters were changed after dive 85 (approx ….hrs) with no sign of water ingress into the system.

5.5 Manipulators:

The port manipulator was used for the majority of sampling work during the cruise. The jaws were slow to open on numerous occasions. Their operation was improved when the jaws were stripped and cleaned of rock debris.

Due to a series of ground faults and subsequent loss of control, the stbd manipulator was inoperable for the majority of the cruise. Hydraulic cylinders, cylinder control leads, and cylinder potentiometers were replaced on both arms as required in order to rectify ground faults. Once all available spares were used it was decided to concentrate on keeping one arm operational.

Both arms require a full service by the manufacture. Type and quantity of spares required needs to be re considered.

5.6 Pan & Tilt Units:

These worked well for the duration of the cruise.

During the steam to the Azores (approx mid cruise) both units were removed and the two off fixing screws were tightened. Unfortunately due to the fact that the new comp line was disconnected the units had to be removed again for bleeding.

5.7 Doppler:

The 300 kHz Doppler was used for the duration of the cruise. This worked well with no problems reported.

A new doppler mount was manufactured during the mobilisation period. This raised the height of the doppler, and was of a more robust construction than the original bracket.

5.8 Cameras:

3 Chip Atlas:

This camera performed without incident for the majority of the cruise. It was connected to a different sub-mux after zoom/focus/iris functions failed due to loss of the control data connection. (See vehicle electrical system comments; telemetry tube).

Pegasus Pilot:

This worked well for the duration of the cruise. There are particles inside the optical dome that need to be removed.

Pegasus Science:

This worked well for the duration of the cruise. There are particles inside the optical dome that need to be removed.

Scorpio digital still with flash unit:

The flash unit worked well for the duration of the cruise. A ground fault arose on the camera. Cleaning the connector, which showed signs of corrosion, temporally solved the problem. This became problematic and the camera was replaced with the spare one.

The spare camera did not operate when installed. Its ID number needed to be changed via the manufacturer's controlling software. The camera then had to be opened up to change the switch to enable the flash to become operable. The camera was opened up and worked on in a dry cold environment. Silica gel was placed in the back of the unit to absorb any traced of moisture.

The sighting of the strobe light should be addressed. In its present position it creates a large shadow from sample baskets when taking images in front of the vehicle. Positioning it on the light bar as far away from the camera as possible should improve the overall lighting. The present position is acceptable when rock baskets or other large sampling devices are not used.

5.9 Lights:

The vehicle is fitted with three HMI lamps each rated at 400Watts each. They provide the main source of illumination for the vehicle. All HMI lamps performed without incident, however the central HMI lamp was pulled free of its mounting position on the vehicle light bar during recovery on one occasion. The lamp remained attached to the vehicle by its electrical cable and was re-fitted. Inspection of the lamp unit showed no permanent damage.

5.10 Lasers:

Two red 14mW laser units are fitted to the science pan and tilt to provide scaling on video displays. The units performed successfully without incident.

5.11 Sonars:

MS2000:

Ceramic capacitors and ferrite beads were installed on the power lines located in the stbd junction box. This was to filter out the electrical power that the vicor power brick generated in its power line. This filtering improved the noise level on the power line going to the SM2000 head. Viewing the swath data display showed a noticeable improvement. A better and more permanent filter should be considered for future operations.

MS1000 Profile:

The MS1000 profile sonar appears to have a problem providing a proper image. The image shows range but as the display sweeps it looks as if the head is stuck looking permanently forward.

This will need to be inspected and most likely returned to Kongsberg for repair.

MS1000 Imaging (Fwd):

The MS1000 imaging (avoidance) sonar failed early on in the cruise and was replaced with the MS1000 imaging sonar. This sonar had been returned to Kongsberg after the last cruise because it had an intermittent “spoking” effect on the display. It was returned along with an invoice saying that they could not find anything wrong with it, other than topping it up with some oil.
It was noted on inspection of the unit (when opened up at sea) that one of the capacitors was burnt and the adjacent connector was melted.
This will need to be returned to Kongsberg for repair.

5.12 Digiquartz Pressure Sensor:

The digiquartz pressure sensor worked well for the duration of the cruise.

The sensor ser. No 89418 that was sent away for repair after the last cruise due to it having an unstable output was returned by the manufacturer, saying that they could not find a problem with it. It was connected to the vehicle after returning its configuration back to the correct settings for Isis and it showed a stable output when run aboard on deck.
This sensor should be tested in a pressure pot or used on a non-critical dive in the near future to ensure that the problem was not pressure related.

5.13 CTD:

The CTD System that is integrated into Isis's systems is an Idronaut Ocean Seven 320 Plus. The 320 Plus contains two Temperature probes and two Conductivity probes for added redundancy and to avoid data drift during long deployments. The system also includes a high accuracy pressure sensor rated for 10,000 dbar. The system itself is highly configurable and can have many additional analogue signals installed directly into the CTD which removes the need for additional cabling and externally mounted instruments. The CTD has not been used successfully previously due to recurring ground fault issues with the O2 sensor. This sensor was not used during this cruise and the CTD itself worked well. There were some problems with the computer running the CTD Software which caused the

CTD Deployments:

During the first dive (Dive 79) the CTD had a hard ground fault even when isolated. ISIS was recovered and the CTD removed. The CTD was reinstalled prior to Dive 83. The CTD failed to communicate several times, however an attempt to download data from its internal memory revealed that it could in fact communicate and once data was removed from memory the CTD communicated without issue.

The display of data was not as expected from the conductivity sensor on the first dive. The CTD has a secondary sensor set and this set was set as the sensors to use on the display and all data displayed correctly. No data was lost from the dives where the CTD was not displaying correctly as CTD logged both set of sensors, however by default does not display it.

The CTD later failed during Dive 87 due to the reinstallation of the LSS. The CTD suffered a ground fault and was isolated.

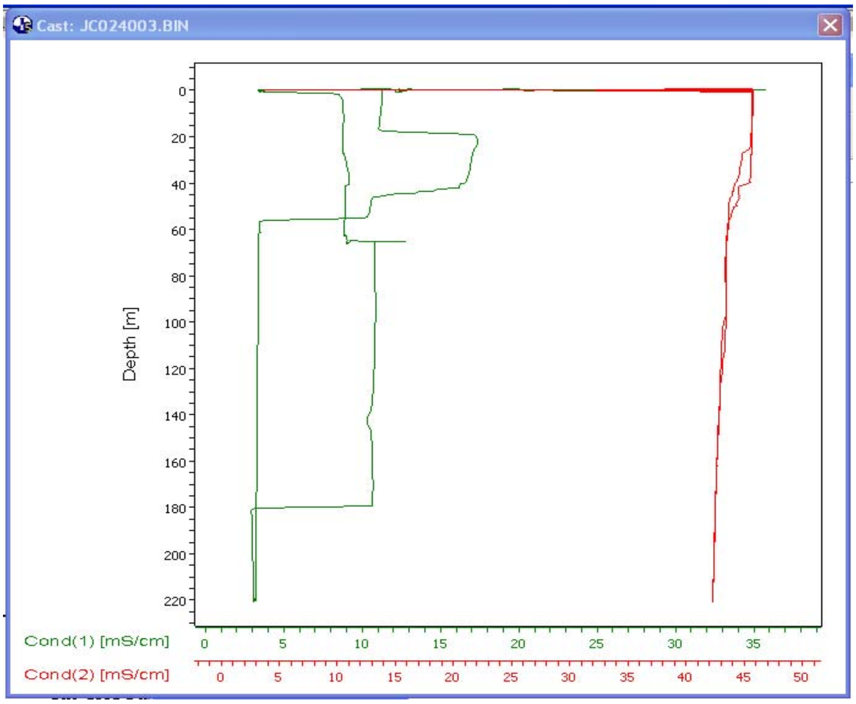

Figure 20: CTD Data Dive 86 Showing Conductivity Issue

(Green Cond 1, Red Cond 2)

CTD File Formats:

The CTD software is known as REDAS 5 (Real Time Data Acquisition Software). The Software itself is not very intuitive, however it is the only way of reading their RAW and BIN data format.

The RAW data files contain all the raw data from the CTD itself in a form of data packet containing the status of all instruments attached and a checksum byte, which enables the error check on the received data to be carried out by REDAS5. Un-correct data is kept in the RAW file but is not considered by data processing and conversion algorithm. Data in a RAW data file is linked to a DATA header file containing the cruise, cast information and a probe descriptor. The probe descriptor contains the information (calibration values, etc..) needed by REDAS5 to process RAW data file.

The BIN data file contains values extracted from RAW files and received from a probe. The Binary file is optimized to give fast data access during the show of plot and/or numerical value. The binary file is created either by a standard acquisition session or by reading and then converting a raw file (post-processing). At any time it is possible to save the present cast as a binary file. Calculated parameters like salinity, potential temperature, Density, etc. are re-calculated on the fly each time they must be shown. Data received from the probe are before stored in a Raw file and then are on the fly filtered and processed using the configurations and data acquisition settings. At the end filtered and processed data is stored in the binary file.

The TXT Files are exported data files containing both sets of Conductivity and Temperature and also include the pressure and time. The files can be reprocessed with any time format or separation format by using the REDAS software and re exporting. The Export settings can be altered in the Configuration > Configuration > Data to Text

Reading RAW Data Files:

Unfortunately the software is very restrictive and cannot find data if it is not in the correct directory, with the correct *.cru file.

In order to read in files to REDAS 5 you need to:

Have a directory called JC024 in the C:\REDASDATA directory.

Have the JC024.cru file in C:\REDASDATA\JC024\ directory

Have all Raw Files in C:\REDASDATA\JC024\RAW

Continue by opening the files:

File > Open > Select JC024 and Cast Number

To Export Data Files

File > Export as text > Current Cast

5.14 WHOI Magnetometer:

The replacement cable supplied by M. Tivey was fitted at the start of the cruise and no further cable issues were noted for the duration of the cruise.

The data from the Magnetometer was logged onto Techsas at 10Hz via the ROV Prizm Moxa box. A problem was experienced with the Maggie driver during the first dive. Following the dive, the driver problem was corrected after which no further problems were encountered. The data from the first dive was recovered by back working the data to allow for the problem in the driver. A mV to nT conversion factor has been hard coded into the Techsas driver to allow SDIV+ to display the correct units.

5.15 Electrical Systems and Wiring:

The high voltage tube, low voltage tube and the power junction box operated correctly and were not touched during the cruise

Power to several instruments failed simultaneously during the cruise. The commonality between the instruments pointed to the 485 submux daughter board for controlling the wecons. Topside and bottomside boards were changed but the problem remained. The original boards were reinstalled. The only commonality was split between two wecon busses. RS485 bus most likely held up by one of the wecon boards bus drivers failing. The suspect board was replaced and the problem was resolved. The suspect board was then reinstalled and the fault never reoccurred. The spare board was again reinstalled and the original board marked as suspect. It possibly has a poor bus connection or else an intermittent fault tying up the RS485 bus. The board 10031 revB s/n 7-1-7 was marked as suspect and needs to be assessed upon return to Southampton. Also noted in the spares box was another board also marked as suspect, possibly intermittent.

The serial comms to the Atlas camera failed. It was found to be the downlink RS232 line that had failed; most probably bottomside. This was resolved by patching the serial wiring into the ROVNAV circuit in the stbd junction box and swapping over the prizm d-types topside.

On return to Southampton, the submux board needs replacing and the wiring put back to its original location.

5.16 Altimeter:

The altimeter failed early on in the cruise. It was replaced with the spare and functioned correctly for the remainder of the cruise.

This will need to be returned to Kongsberg for repair.

6. Isis System Topside:

6.1 Video Tilters:

Two video titlers were used to timestamp time/date, heading, depth, altitude and doppler height onto the Rec 1 + Rec 2 DVD feeds. The overlays worked well for the duration of the cruise and no problems were noted.

6.2 ROV Gigabit Link to the Laboratory:

Following the problems encountered during JC21, several modifications were made to the system during the mobilization period for JC24.

1) The PCs mounted in the AcoustiRack were completely re-wired and re-located to improve the airflow through the rack. Also the rack has been moved away from the door to allow rear access and the back has also been removed to prevent heat build up.

Most of the generated heat appears to be coming from the Apple equipment.

2) As part of the phasing in of the new HP server PC’s two of the old CyberResearch PC’s were removed from the rack.

3) Different patch connections between the main lab and the ROV control van were used and this immediately resulted in a reliable gigabit link to the laboratory rack.

4) The Apple X-server was swapped to use the newer Spare unit which is running more recently updated software.

The AcoustiRack now runs at a far more acceptable internal temperature, even during the hot weather experienced in Costa Rica during the mobilization period. I believe that changing the rack setup coupled with the physical cable run to the main lab that the issues from JC21 have been fully addressed.

Following JC24 improvements will be made with the Isis network to Ship network interface to allow more seamless access for Scientists from the ships network.

6.3 Device Controller:

There still appears to be problems when both Joysticks (pilot + science) are in use simultaneously which caused numerous issues during the cruise. On numerous occasions the software had to be re-started following camera runaway situations which were mainly caused by the addition of a new P&T unit at the beginning of the cruise. The units are generally to slow for most operations; the interface with the Scorpio Camera is 'clunky' and was commented on numerous times by the science users.

6.4 Techsas PC:

A new HP server PC running Techsas v2.35 was installed during the mobilization period. The new system was configured to write to both of its internal HDD's and this data was mirrored to the Isis RAID server on a 5 minute period basis.

The system performed well and no re-boots of the system were required for the duration of the cruise.

A problem with logging data from the Crossbow was identified during the cruise and a fix for this is now in place.

6.5 Caraibes PCs:

Two PCs were made available for swath data processing. The Cyber Research computer is slow and struggles to function well once large data files are being used.

The HP Proliant server PC worked well with the new version of software that was installed. Previously his machine would not allow 3D graphics to be performed using earlier versions of CARAIBES. However there are still some functions where the graphics do not work correctly. Although a couple of graphics cards have been tried in this computer, a satisfactory implementation providing dual screen operation while running Linux has yet to be resolved.

To aid future operations a high spec. computer with dual screen graphics should be used.

CARAIBES software:

The new version of CARAIBES 3.4 was installed onto the two machines. It operated well on both machines. The new version was capable of reading all the necessary files for processing the swath data as well as being able to address the new Isis depth parameter which is now being logged on the TECHSAS data logger.

CARAIBES was used to process the swath data that was obtained via the MS2000 system. Data from two dives in different areas was collected and worked up, producing good quality bathometry charts.

The processing was undertaken by scientists aboard (mainly Tim Lebas); on his laptop with an extra screen. This software was found to be satisfactory though there are a few minor functions that could be addressed for future revisions. The main problem being that not all modules link together without being run via a linking file. This will be presented to IFREMER to comment on and to address.

There is the occasional pitch correction error with the data. It has not been obvious where the problem lies. Initial inspection shows that the file created by the MS2000 system has the occasional ping time error at the same time a ping or two are dropped and the μS ping counter gets reset. This will have to be inspected and resolved upon return to Southampton. Although not a great degradation to the data and is not visible once the data is contoured, the cause of this fault should be discovered.

6.6 Sumatra PC:

The computer worked well for the duration of the cruise. This system was used by the scientists for the duration the ROV was is in the water providing essential survey information in real time.

To aid the TOBI survey, SUMATRA was configured so that a real time display of the ships position over a backdrop of swath data was made available in the main lab close to where TOBI was being operated. This made flying TOBI much safer. A real-time survey package such as this should be part of the ship’s standard provision for scientific operations.

Now that this system is deemed to be operational a spare computer should be purchased to enable a quick change should the present one fail.

Isis, ship and SWATH data were displayed in real time together with waypoints and survey lines. Backdrops of ships swath, Isis swath and TOBI sidescan were also displayed.

SUMATRA software:

At the start of the cruise the latest version 9.2 of ArcMap was installed. There were many issues when running the SUMATRA software supplied at the start of the cruise. After some emails to and from IFREMER it became obvious that the version we were using differed from the one they were working from. A new and later version was copied using ftp from their ftp site. This new version loaded and ran well. However it exhibited the main problem that the earlier version showed, i.e. it would not read any file created from the administration mode. IFREMER are looking into this problem and we are awaiting an answer. This problem should have been addressed before the cruise started but delay in returning airfreight prevented any testing prior to it being sent out again.

6.7 Event Logger PC:

A problem with the Category field being limited to 50 characters was identified at the beginning of the cruise and a fix was put in place after the first dive. No other major problems were encountered with the system other than when a Science user re-booted the PC and the Framegrabber server was not correctly re-started. Fortunately this was noticed at the time and no images were lost or otherwise affected.

6.8 SM2000 PC:

At the start of the cruise the hard drive became corrupted and a new drive was installed. This made the system run more reliably. However the processing power was pushed to the limit in the mode that was being operated. If the range for sampling was increased from 200m to 300m the cpu usage rose considerably to a point that was close to it becoming unstable.

This computer should be replaced with a new machine that is considerably faster. At the same time a new PCI STP board should be purchased and installed. This would make this a powerful system for processing swath data and may eliminate the occasional ping being dropped or output suspect data. The present system would then become a spare should the new system fail. SWATH being such a high priority operation during a cruise should have a good backup should there be a failure. A new computer and STB would be an acceptable investment, however a spare sonar head would be a major investment.

The possibility of changing its operating system to XP should be looked into.

SM2000 swath files summary:

See Appendix 3.

6.9 MS1000 PC:

This computer appeared to work successfully for the duration of the cruise.

6.10 Topside PC:

Time permitted to correct the problem the Isis system has experienced since day one with the topside code crashing at switch on. The was traced to a problem with a function parsing messages coming from the Wecon boards. Binary characters that were being passed to a conversion routine were the cause of the crashes and the code has been modified to prevent these crashes from occurring.

At the end of the second dive, the PCI Digibox card failed for an unknown reason (possibly static or PSU related). Either way the card was rendered inoperable and the spare system was used without further problems for the remainder of the cruise. The PC was subsequently tested and operation with a new Digi-PCI card works so there is still a working spare system available.

6.11 Videowall PC:

Worked well for the duration of the cruise, no problems noted.

The CLAM software was upgraded to include Isis depth directly from the depth sensor. A display showing Isis depth and Isis assent/descent rate was also added to the existing display.

A display option that would either fill the full screen or be used with the picture in picture was also updated to include Isis depth and rate.

Two video wall templates were created so that one large image and three small images could be displayed on the large flat screen in the main lab or else the option for two large images and four small images could be displayed. The first two images from either option can be selected to display the images from any of the cameras from the eng1 and eng2 buttons on the video mux.

The large screen display was used in the main lab to show these images for scientists to watch when not in the control room. This display was also used for other purposes, such as presenting data during science meetings. Such a display should be considered to be a permanent fixture provided as part of the ship’s fitted systems.

6.12 DVLNAV PC:

A new HP server PC was installed during the mobilization period which worked well and ran at around 8-9% CPU. Automated scripts were also used to mirror the data to the Isis RAID system at 15 minute intervals which worked well.

A 16 port Edgeport was used in place of a Digibox for the first time and this worked well and no problems were noted.

6.13 Minimac PC:

This PC seems to regularly freeze which looks like it might be caused when the keyboard and mouse are "disconnected" as the KVM is switched. This problem will be addressed post cruise and caused no major problems during this cruise.

6.14 Pilot/Engineer PC:

Worked well for the duration of the cruise with no problem encountered.

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6.15 DVD / DV Recording Setup:

Recording setup was as followed:

3-Chip (Atlas) -> DVCAM Master, S-Video

3-Chip (Atlas) -> DVCAM Slave, S-Video (buffered)

Pegasus (Science Cam) -> DVCAM Master, Composite PAL

Pegasus (Science Cam) -> DVCAM Slave, Composite PAL

3-Chip (Atlas) -> DVD1, With video overlay, Composite PAL

Pegasus (Science Cam) -> DVD2, With video overlay, Composite PAL

All recording to tapes went well with no notable problems. A few issues with scratched DVD's and accidental changing of recording sources occurred but problems were addressed quickly and the Science party were vigilant with post tape screening.

DVCAM tapes used – 360

DVD discs used -- 270

6.16 Minifilm Recording:

Minifilms were recorded on two separate PC's and other than the Adelie software crashing on exit no problems were encountered. The 3-Chip and Science cameras were recorded without overlay every 5 seconds as jpeg images. Owing to the large number of individual files, the images have been tarred on a dive by dive basis to ease distribution and copying of files at the end of the cruise.

6.17 Backup / Data Archiving:

Two 1.8TB MyBook's (configured as Fat32, RAID-1, 932GB) were passed to the PSO containing data from the IsisData and IsisVideo shares amounting to approx 1TB of data. A copy of all Swath/Techsas data files was also passed to Tim Lebas on a 500GB MyBook

7. Isis Topside Technical Details:

7.1 Ship Network Connection:

The connection to the ships network was used for NTP access primarily and also to pass a video stream to the bridge for monitoring the ROV in the water. The connection worked fine and no issues were encountered. During the cruise, DNS entries have been added to the ships system to make Science access to the ROV computer network easier during future cruises.

7.4 Apple X-Server / RAID-Server:

Intel based server was used for the first time to ensure that problems as seen on JC21 were not re-encountered. The server worked well for the duration of the cruise. Network mount points were added for:

IsisData	0.93TB	(931.25 GB)
IsisVideo	2.27TB	(2270 GB)
IsisTeamOnly	0.47TB	(466 GB)

The memory Band 3 and 4 has been running at 127deg (off-scale) causing an alarm.

7.5 Bender Ground Fault Unit – Isis:

No operational issues were noted during the cruise.

8. ISIS Dive Summary (hrs run)

Cruise No.	Dive No.	Dive Hrs.	At Bottom Hrs.	Max Depth (m)	System Total Hrs
JC024	79	24	19	3100	
JC024	80	31	29	3000	
JC024	81	38	33	3600	
JC024	82	23	21	3576	
JC024	83	14	9.5	3341	
JC024	84	1	0	-	
JC024	85	18	14		
JC024	86	1	0	-	
JC024	87	37	33		
JC024	88	31	27		
JC024	89	19	15	3523	
JC024	90	14	10		
JC024	91	39	35	3100	
JC024	92	43	39		
JC024	93	31	27	3109	
JC024	94	0	0	0	
TOTALS	**16 (dives)**	**364**	**311.5**	**3600**	**1635.5**

Isis Video Surveys

Isobel Yeo

Video data were recorded on all Isis sampling dives (JC24-79, JC24-80, JC24-81, JC24-82, JC24-83, JC24-84/5, JC24-88, JC24-89, JC24-90, JC24-92, and JC24-93).

Isis Cameras

Atlas: Atlas is a 3-chip 850 line colour camera with a 14x optical zoom. The camera is too large to be used as a pan and tilt and is mounted on the ROV in a fixed position which can only be adjusted while the ROV is on deck.

Pegasus (Science Pan and Tilt): The Science Pan and tilt camera is a 560 TV line, low light, colour camera with 12x zoom. It is mounted on a pan and tilt unit, which was available for science operation during the dive, except during sampling when it was required by the pilots. This camera was the main one used by the watch leaders for scanning the survey area and zooming in on points of interest.

Scorpio: Scorpio is a 3.34 Mega pixel digital still camera with a 4x zoom. It was used to take publication-quality pictures of both geology and biology. These were then downloaded to the Raid server at the end of each dive, and were available to the science party. They are also available (along with all the Isis data) on the hard drives passed to Durham University at the end of the cruise.

Isis also has three other fixed cameras, which were not usually used for science. Two Aurora Colour Mini cameras, one up looking and one directed at the baskets, and one Mercury Low Light Monochrome rear looking camera (which was occasionally recorded instead of the Pegasus when going down steep slopes).

Video Recording

DV Cam Tapes: We had the capacity to record from 2 channels, in this case the science party elected to record video data from the Atlas 3-chip camera and the Pegasus Pan and Tilt camera, with the exception of one watch, which used the Aft Cam for several hours to record footage while the ROV was travelling down a slope. In addition, these two channels were duplicated onto a second set of DV Cam recorders which produced back-ups in real time. We recorded onto DV Cam tapes lasting 3 hours and tape changes were staggered so one set of tapes was always recording. Tapes were numbered cruise number- Isis dive number- tape number – camera recording, composite or s-video – master or backup (e.g. tape 26 recording backup Atlas composite footage for dive 89 would be labelled JC24-89-T26-AC-B). All tapes recording the same period of time have the same tape number, so for every number there are 4 tapes. All tapes have been checked and found to have recorded correctly.

DVD Recorders: There were 4 DVD recorders available, capable of recording from any of the video channels. The science party elected to use two of them to produce copies of the video footage being recorded on the DV Cam tapes with digital overlay of date, time, altitude, heading, depth and Doppler positioning. DVDs were numbered using the same system as the tapes, but with a DVD number in place of the tape number above (e.g. D26 instead of T26). DVDs lasted 2 hours, so there are more DVDs than tapes and consequently there are generally different tape and DVD numbers for the same time period.

All DVDs were checked. On one occasion the recording channel on one of the DVD recorders was switched accidentally resulting in several DVDs not recording video. In these cases new DVDs have been recorded from the DV Cam tapes to produce a full set of dive DVDs. In these cases the overlay is lost, however the DVD recording the other channel at the corresponding time was recording correctly, so the overlay information can be cross referenced if needed.

DVR Networked Video Recorder: In addition to the above, footage from 4 of the video channels (in this case Atlas, Pegasus, Pilot Pan and Tilt and Aft Cam) was recorded onto hard drive with a h.264 compressed resolution at 7 frames per second per channel. This allowed real time streaming so the video could be viewed over the ship's network, notably on the 40” flat screen monitor mounted in the lab. This data was made available on the RAID server after each dive and the hard drive was passed to Durham University at the end of the cruise.

Adelie Software

Adelie was used to create Mini Films from the Atlas and Pegasus video channels (the same channels being recorded to DV Cam and DVD). These Mini Films consisted of framegrabs taken from the video channels every five seconds, which were then stored in a dive directory. These framegrabs have now been sewn together to produce an AVI format movie for each dive.

While each individual frame grab contains the time it was captured in its name, it has so far not been possible to date stamp the frame grabs themselves, meaning these movies will be of limited usefulness outside of providing a dive overview.

Frame grabs and Event log

During a dive, one of the science party would enter events into the dive Event logger, which would record the type of event, the time and any comments. This produced a narrative of all the dives as part of the same file and accompanies the main log held by the watch leader. This is available on one of the hard drives passed to Durham University at the end of the cruise.

Event log also allowed the scientists on watch to take framegrabs from any of the Isis cameras at any time. These were stored in files labelled with the dive number and were made available on the RAID server and the shared drive ‘Drobo’ after each dive. They are now available on the hard disk passed to Durham University at the end of the cruise.

On Board Uses of Video Data

A DV Cam player and screen were provided allowing the science team to check and review DV Cam tapes on board. Tapes and DVDs were used to:

- Produce a map of sediment cover along the dive tracks
- Produce short films of sampling operations which were then linked to the working ArcGIS file
- Take framegrabs of sampling sites for sample summary sheets
- Review important localities to aid interpretation

In addition framegrabs were used directly after each dive to aid sample identification.

Post cruise Distribution of Video Data

The master copies of the DV Cam tapes for both Atlas and Pegasus cameras will go to Durham University. The backups will be sent to Southampton for copying, the originals to be kept by Southampton and the backups passed to BODC.

The original DVDs for both Atlas and Pegasus cameras will also go to Durham University. Institutions requiring copies of the DVD data will provide 1 Tb hard disks to Durham, where the DVD video data will be copied across.

All framegrabs, Mini Films, and digital stills will be copied to the main Isis data hard drive passed to Durham University at the end of the cruise. As with the DVDs, institutions requiring this data will provide hard disks onto which it can be copied.

The compressed 4-channel, low resolution video is stored on a separate hard drive which will also go to Durham University.

Current Expected Copy/Distribution Requirements

Institution	Expected Video Copies Required
Durham University	None. Original master tapes, DVDs and all Isis data hard disks stored at Durham.
Southampton University	Both Atlas and Pegasus DVDs.
Woods Hole Oceanographic Institution	Both Atlas and Pegasus DVDs. Scorpio Images, Framegrabs, Mini Films
The Open University	Both Atlas and Pegasus DVDs.
Marine Geology Department at INETI, Portugal	Pegasus DVDs only. Mini Films.

ISIS Magnetic Processing

Maurice Tivey

Magnetic data were obtained as digital ascii comma separated value (CSV) files from the ISIS **Techsas** data folder. The WHOI magnetometer data is stored in the "**mwhoi**" folder. These data are read into MATLAB and saved as a time-stamped struct array. From the "**iocts**" folder the ISIS Octans attitude data are read into MATLAB and saved as a struct array. The magnetic and Octans attitude data (pitch, roll, heading) are at a data sampling frequency of 10 Hz and are merged together onto the same time base. This merged 10 Hz data stream is then used in the calibration of the magnetic data. For each dive except one (Dive 81), ISIS stopped at 1000 m water depth and completed a 360 degree turn anticlockwise followed by a clockwise rotation. The data indices of these turns are located in the data file and then extracted to do the full vector calibration as described earlier in the TOBI magnetic calibration section. A typical calibration report and plot is shown below and in Figure 21.

```
ISIS Calibration - Dive 87
Latitude/Longitude      45.5000000     -27.8733000
Latitude/Longitude (deg min):   45    30.00  -27   -52.40
Indices: 39478 43059

 Offset between raw observed and predicted field:
 X-component Mean diff:   396.57 nT   RMS diff:   224.27
 Y-component Mean diff:  1213.45 nT   RMS diff:   582.22
 Z-component Mean diff:  1788.96 nT   RMS diff:  1236.22

 Offset between corrected and predicted field:
 X-component Mean diff:    46.89 nT   RMS diff:    28.05
 Y-component Mean diff:    45.26 nT   RMS diff:    28.93
 Z-component Mean diff:    19.22 nT   RMS diff:    15.17
 Total Field Mean diff:    19.57 nT   RMS diff:    15.23

 Calibration Coefficient Matrix
   1.01542   -0.02331    0.01569   -878.74
   0.03792    1.01147    0.01320  -2024.55
  -0.08785    0.02029    0.92706   1916.95

Field Parameters:
Latitude/Longitude (dec deg):      45.5000000     -27.8733000
Latitude/Longitude (deg min):   45    30.00  -27   -52.40
Average Magnetic Inclination 61.668 degrees
Average Magnetic Declination -11.729 degrees
IGRF Magnetic Inclination 61.669 degrees
IGRF Magnetic Declination -11.729 degrees
```

```
Average X-component 21885.18 nT
Average Y-component -4543.65 nT
Average Z-component 41457.43 nT
 IGRF X-component 21885.17 nT
 IGRF Y-component -4543.58 nT
 IGRF Z-component 41457.44 nT

Original Total Field variation:  3215.06 nT
Corrected field variation:   209.07 nT
```

After the calibration matrix has been calculated the ISIS depth and altitude data are loaded into MATLAB from the "**icsv**" folder. These data are at a 1 Hz sample rate and the magnetic and attitude data are decimated to match the 1 Hz sample rate. The calibration coefficients are then applied to the entire dive data set and saved in a MATLAB binary file (e.g. is_87_magf.mat).

At this stage the magnetic data is ready for merging with ISIS navigational data obtained from the "**igga1**" folder. The navigational data were first filtered using a 2-point window median filter (to remove single spikes) and then averaged with a running mean over a 20 sample window. The smoothed navigational data were then merged onto the same time base as the magnetic and attitude data ready for further analysis.

Initial Magnetic Analysis

The individual profiles can be extracted, continued upward to a level plane and inverted assuming two dimensional sources. The corrected total magnetic field data, centre beam bathymetry (depth and altitude) and ISIS depth can be output to ascii xyz track line files in lat, long coordinates:

```
is_XXtf.llz – total magnetic field (nT)
is_XXfdp.llz – fish(ISIS) depth (m)
is_XXcbth.llz – centerbeam bathymetry (m)
```

These files are then used to interpolate onto a profile using 'mkprofl.m' or onto a grid if the data are part of an areal survey. For a profile, the magnetic processing is straight forward following the usual projection onto an azimuth perpendicular to the trend of the axial ridge (105 degrees in this case) and re-sampled into equally spaced points (mkprofl.m) and then upward continuation to a level plane (guspi.m) and inversion for magnetization (inv2d.m). Typically the following ascii files are produced:

```
prfXX_l#.bth  - centerbeam bathymetry (m)
prfXX_l#.fdp -  fish (ISIS) depth (m)
```

```
prfXX_l#.fld  - observed total field intensity (nT)
prfXX_l#.gup  - upward continued field (nT)
prfXX_l#.m2d  - computed magnetization (A/m)
```

An example of the profile data is shown in Figure 22.

For the two ISIS sonar dives (87, 91), the merged and corrected magnetic data were interpolated onto a grid using the GMT *surface* and *nearneighbor* commands. A grid spacing of 0.5 arc second equivalent to approx. 15 m was used for these grids. The processed EM120 bathymetry was re-sampled to match the magnetic grid spacing for a crude estimation of seafloor depth. Three GMT format grids are produced:

```
is_87_tf.grd – total magnetic field (nT)
is_87_fdp.grd – fish(ISIS) depth (m)
is_87_bth.grd – bathymetry (ISIS) (m)
```

The total magnetic field data grid is continued upward to a level plane above the topography using the iterative Fourier transform method of Guspi, (1987). The resultant upward continued field is saved as a GMT format grid:

```
is_87_gup.grd -  upward continued total magnetic field (nT)
```

The upward continued field is then used along with the bathymetry to compute a crustal magnetization using the Fourier Transform approach of Parker and Huestis (1974). This inversion removes the topographic effect from the magnetic field to compute a source magnetization. First, it is assumed the source of the magnetism resides in the underlying crust, which has a constant thickness (0.5 km) with the upper surface defined by the topography. The second assumption is that the direction of the magnetization vector is constant within the source layer (i.e. it doesn't vary with depth) and is parallel to the present day geocentric field direction computed from the IGRF 2005 (Inclination= +61.5, Declination=0).

```
is_87_mag.grd -  computed crustal magnetization (A/m)
is_87_mag_mask.grd -  masked crustal magnetization (A/m)
```

The magnetization grids are re-sampled onto the finer sonar MS2000 bathymetry grid for overlay purposes. These grids are saved as:

```
dive87_mag.grd -  computed crustal magnetization (A/m)
dive87_mag_mask.grd -  masked crustal magnetization
```

Figures

Figure. 21. Plot of ISIS Dive 87 calibration turn with the observed total magnetic field data (blue) and the corrected total field data (red). A residual curve remains on the order of a few hundred nanoTesla.

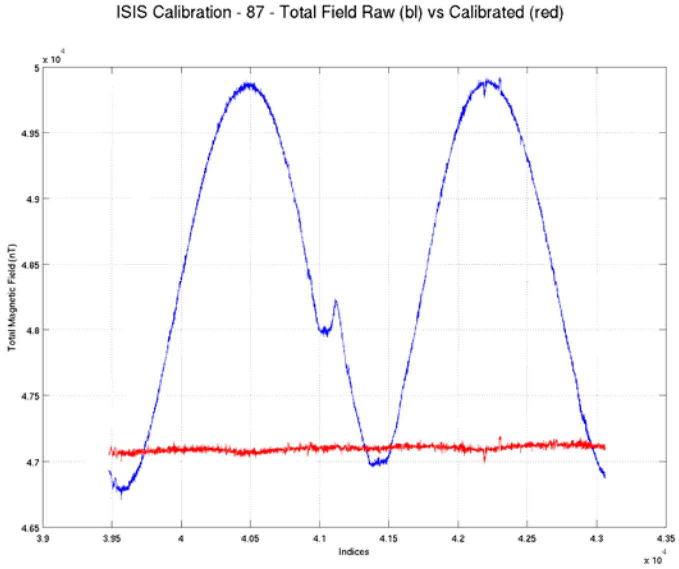


Figure 22. Plot of observed magnetic profile from ISIS Dive 92 that crosses the Axial Volcanic Ridge. Projected azimuth of 105 degrees.

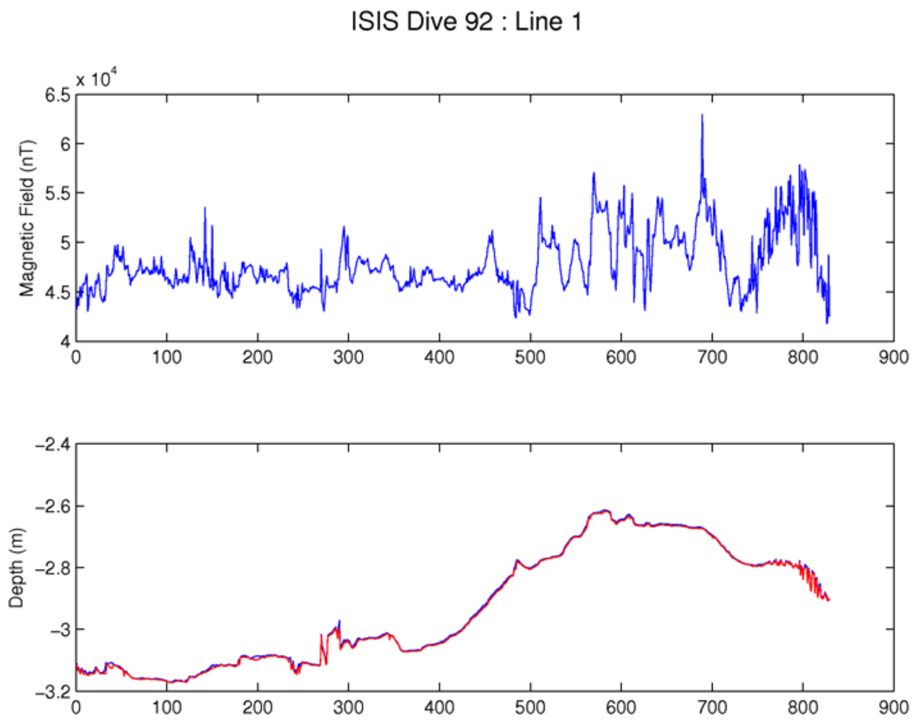


Figure 23. Inversion for crustal magnetization for profile of ISIS Dive 92 showing sharp contrasts in magnetization intensity on the flanks of the AVR. Model layer thickness assumed to be 0.5 km.

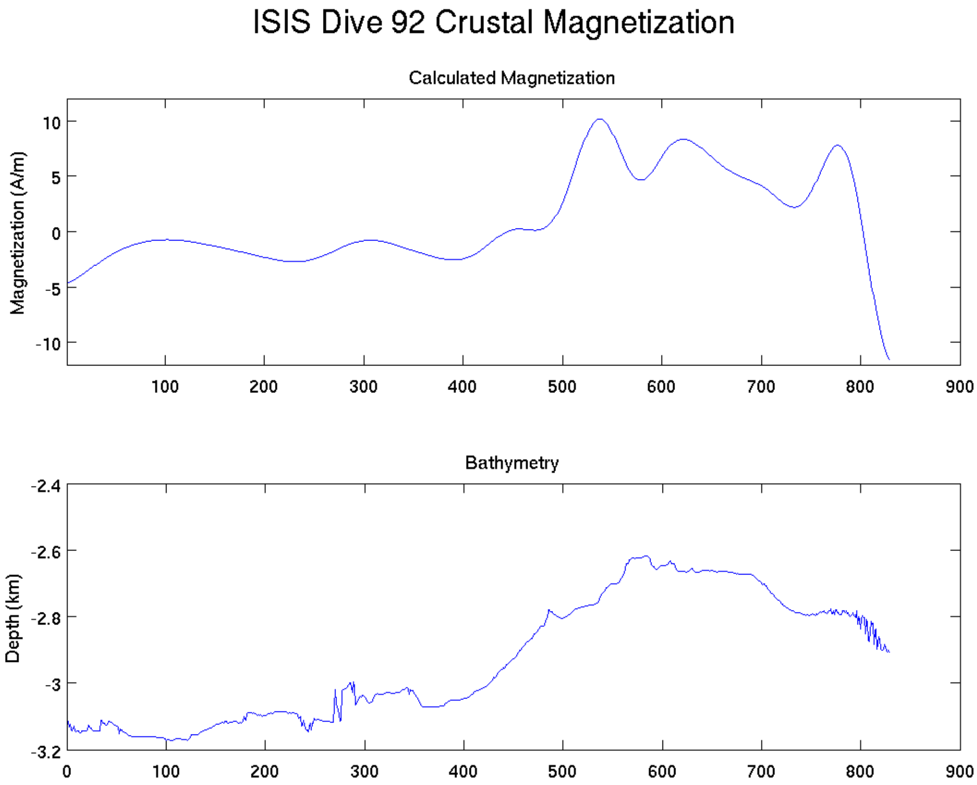
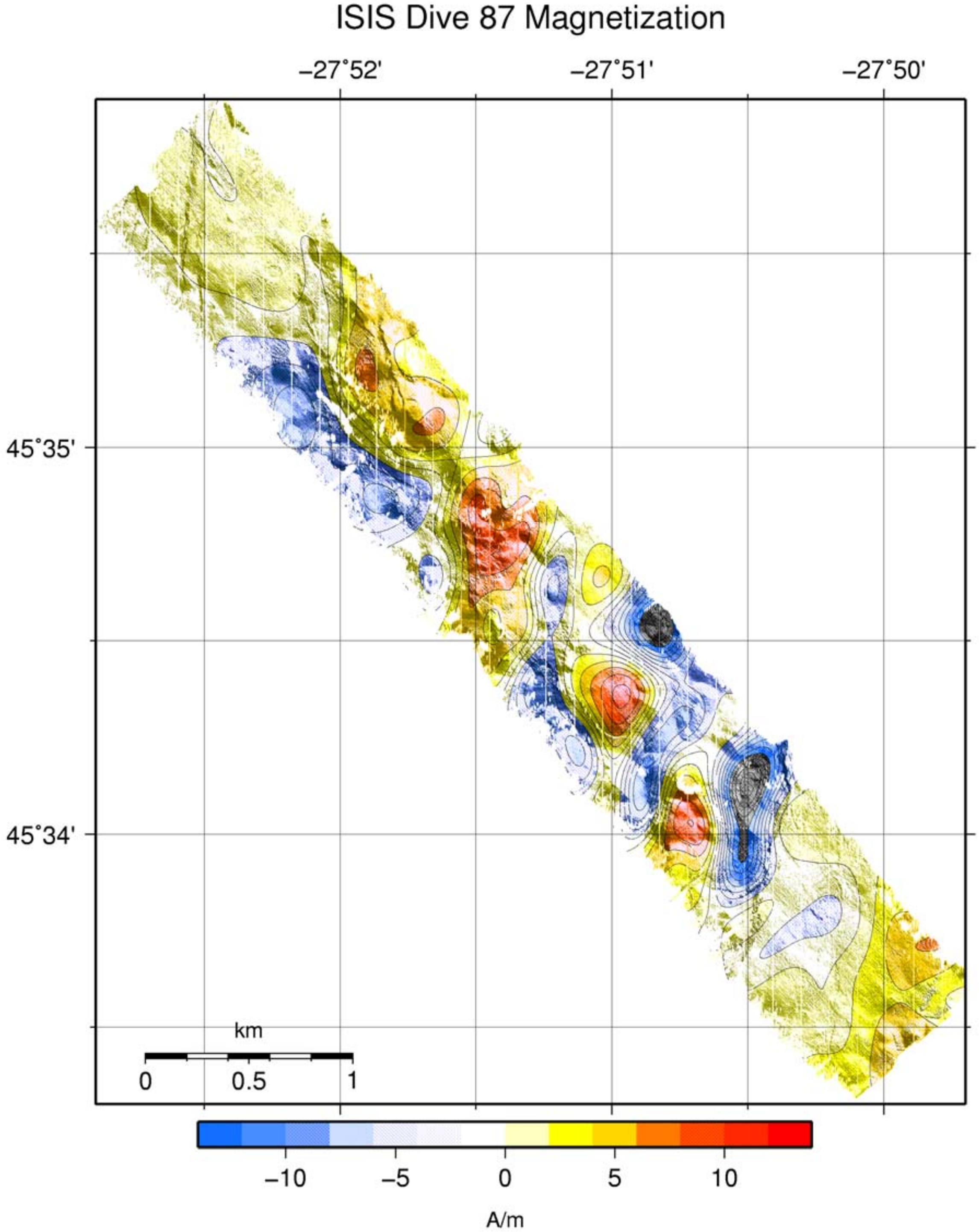


Figure 24. Inversion for crustal magnetization for ISIS Dive 87 showing the strong magnetization of the small volcanic domes of the AVR. Color contours are in magnetization units of Amps/meter while the shading is based on the high resolution MS2000 bathymetry.



Geological Sampling Operations

Bram Murton

Geological sampling using the ROV *ISIS* targeted mainly volcanic rocks although several sediment push-cores were also taken.

A general set of criteria was established for choosing where to sample. These were:

- Contacts between lava flows of different colour, age, sediment cover, morphology, thickness etc. Samples were taken from both lava flow across the contact.
- Cliff scarps that exposed sections through the lavas, with samples taken at the base and top and at intervals in between depending on observed variations in the lavas. If there was no obvious variation, then samples were taken at 10-20 m intervals.
- Terraces where a marked change in slope was observed.
- Flow fronts, often observed as rubble and intact pillows.
- Volcanoes, sampling their flanks, tops and any identifiable eruptive vents.
- Any other unusual feature (e.g. intrusives, protrusions, etc.).

The procedure for sampling was to first photograph the general scene, and then the outcrop. A sample was chosen (ideally to be about 2 kg with as much glass as possible) and photographed before being deposited in one of the colour-coded sample basket slots The frames and basket position was logged.

Retrieval of the samples from the ISIS baskets was done using a strict protocol. During the ascent of the ROV, the frame grabs of the samples were printed and copies of the sample log sheets made. Once secure, the ROV baskets were removed and the samples removed in numerical order. An overseer compared the samples with the frame-grab images to ensure there was no mixing of the samples. Samples were then taken individually into the deck lab. where they were placed on labelled sheets of paper.

Photographs were taken of each sample, and included a standard scale, date, and the individual sample identifier. These were of the form: JC24-{dive #} – "sample #}, with "S" appended for sediment samples.

Each sample was then described on a standard sample description sheet that included: weight, size, shape, type of lava, lithology, petrography, vesicularity, alteration and coating, and an estimate of the relative age was made. These data form the basis of the sample summary log and the sample summary sheets included as an appendix to this report.

The samples were then processed to remove any external glass. The glass was subdivided between the Open University, Woods Hole Oceanographic Institution (one or more of the largest intact pieces of glass) and NOCS, labelled and bagged.

The remaining rock was cut into several pieces on a 150mm diameter diamond saw with slabs gong to both Durham University and NOCS. Each slab had the sample ID written in white paint on the cut and dried surface. All remaining material was bagged ready for archiving at NOCS.

Appendix 5 contains individual sample summary descriptions, organised by dive number. In addition, more comprehensive sample descriptions were entered into a spreadsheet **JC24_RxComp_R1B.xls**. This is too large to include in the printed version of this cruise report, but may be accessed from the same digital directory or on application the Principal Scientist.

Biological Sampling

Kirsty Morris

Introduction

Seamounts and other areas of raised topography, such as volcanoes and haystacks, are associated with higher levels of productivity and diversity than surrounding waters. This can lead to fish aggregations in their vicinity and can attract locally intense commercial fishing, subsequently leading to overexploitation of the area and its associated stocks.

Over recent years the importance of the seamounts as biodiversity hotspots has been noted and there has been an increase in interest both by scientists and governments to ensure that species are conserved to help maintain the biodiversity of the seas and prevent over-exploitation and destruction of these habitats by fishing and other processes. This requires a good knowledge of biology and ecology of the species, however, very little is known about the biology and ecology of most deep-water species due to the difficulties in studying them.

The overall arrangement of the seamounts in Atlantic oceans has been shown to be non-uniform (Smith & Jordan, 1988, Marova & Alekhina 1996). The majority of the seamounts present are from volcanic origin, they may be representative of active plates, single faults or general hot spots upon the seafloor (Marova & Alekhina 1996). From current data 58% of the known seamounts occur in the North and 42% in the South Atlantic (Marova & Alekhina 1996), with the highest abundance occurring between the Charlie Gibbs fracture zone and the Azores (Epp & Smoot, 1989).

Coral formations are often present upon on seamounts creating a higher level of three dimensional complexity within the deep-sea, and increasing the number of niches available for other organisms to colonise. Two thirds of all known corals are deep water species and they can range from single polyps to single colonies right up to reef structures and coral gardens. Deep-sea corals have been known for hundreds of years with the oldest known reference to them occurring in the Natural history of Norway in 1755 (Koslow 2007) but it is not until recently that their importance has begun to be understood. Deep-sea corals can be defined as a “paraphyletic assemblage of organisms belonging to phylum cnidaria” (Morgan *et al.*, 2005).

Deep-sea corals are azooxanthellate Cnidarias so unlike there shallow water counterparts they do not directly relay upon sunlight to survive. They survive in water of 4-13 degrees compared to the 20-29 of their shallow water counterparts, and in a salinity of 32-38.3 ppm.

This project will focus on the soft corals or Octocorals of which there are around 3,000 described species including the tropical species (McFadden et al, 2006). Octocorals are common members of coral reefs and hard-bottomed communities throughout the world and contain species from both tropical and deep-sea ecosystems (Wirshing *et al*, 2005). Octocorals are differentiated from other cnidarinas due to – 8 pinnate tenticles, a unique nematocyst structure, 8 mesentries and other characteristics (Wirshing *et al*, 2005). Octocorals contain three orders Acyonacea (soft corals and sea fans), Pennatulacea (sea pens) and Helioporacea (blue corals) (McFadden et al, 2006).

Traditionally taxonomy has been used to study and identify species by looking at their distinct morphological features. However this has been hampered with octocorals due to a poor fossil record, paucity of morphological characteristics, widespread plasticity and widespread intraspecific variation- an example of which is growth form where some coral species can grow as both a branching colony and have an encrusting form. All of these characteristics make taxanomy a very challenging, labour intensive task which often does not reach a definitive answer.   The problems are exacerbated by the fact that the morphology of a species has been shown to change dependant upon the depth at which it is found and thus the characteristic on which an identification would be based can be lost or changed. This makes species identification from picture and videos alone very difficult.

Despite being an important and relatively abundant there has been very little genetic work carried out on deep sea corals. By using molecular genetic techniques in leiu of taxonomy it is possible to ensure a correct identification of samples collected. Molecular techniques allow the separation of very close sister- groups which is very difficult in traditional systematic techniques. Our current knowledge of evolutionary processes in coral species is poor, mainly due to problems accessing appropriate genetic markers (Costantini *et al*, 2007).

This study aims to improve the understanding of the Octocoral communities present at 45 N 27 W on the mid Atlantic ridge with emphasis on colonisation, growth, reproduction and genetic relations of the coral colonies both to each other and to specimens from other areas. It also hoped to be able to develop good primers for PCR. Genetic analysis of octocorals may also allow seamount interconnectivity and oceanic dispersal of larvae to be investigated by comparing results from different areas (Baco *et al*, 2006).

Methods and results

Isis was used to collect samples of coral at different locations along the active volcanic ridge (AVR) following the set dive plans for rock sampling. The Coarls were collected using the manipulator arm and placed into a “bio box” on the starboard side swing arm of the ROV. The Bio box consisted of a rectangular PVC box with a lid secured down by an elatic strap being pulled over a bolt by the manipulator arm (figure 25)

.

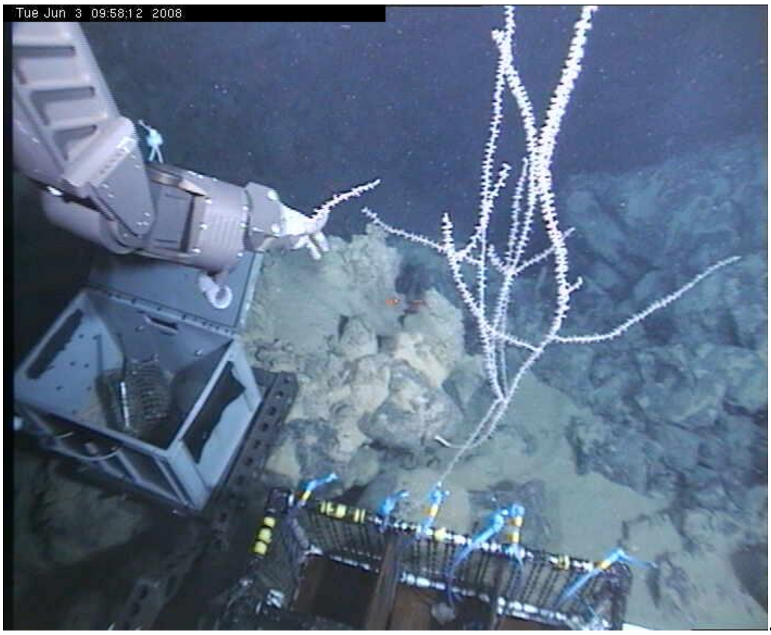


Figure 25- ISIS Arm places sample into bio box.

Frame grabs were taken of each sample from the science pan and tilt camera as it was placed into the bio box. These pictures are then printed off to allow a comparison and thus the identification of the samples from the bio box once on the deck. Once the sample had been selected a log was taken to include, longitude, latitude, depth, time date, substrate type, shape of coral and any extra notes which may be required i.e. shape of the sample taken.

There was a problem with the recovery of some samples where by the flesh and polyps had become detached during the ascent to the surface leaving only the internal skeleton rendering them unusable for any further work. To try and counteract this problem a quiver system was implemented. This involved the creation of 12 quivers using core tube of 40cm high being secured into the bio box with cable ties and rope. Drainage hole were drilled into the quivers to allow the water to drain at the surface. This allowed the samples to be easily distinguished from one another via there placement as well as allowing the samples to have a reduced water flow and thus increase the survival of the corals on the way to the surface. Figure 26 shows a coral being placed into the bio bow once the quiver system was in place.

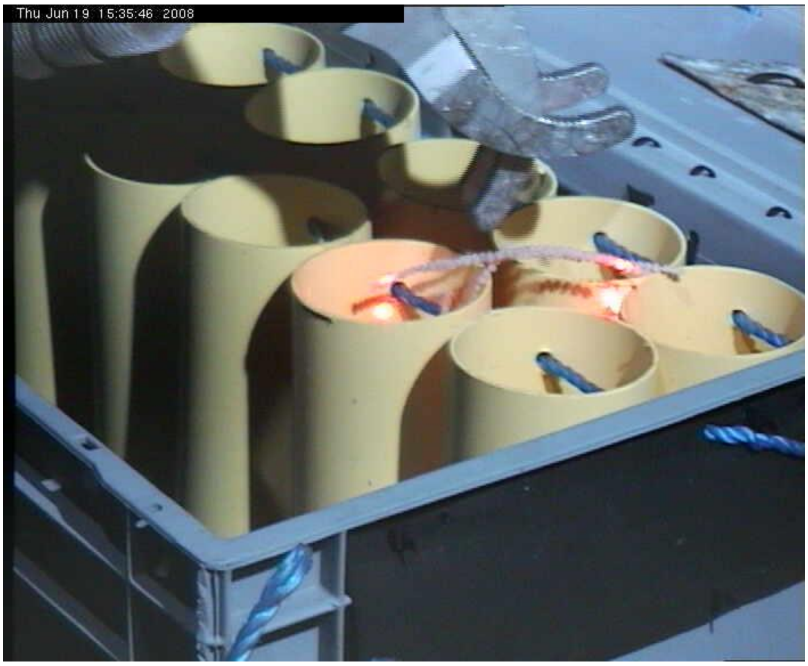


Figure 26. sample being placed into quiver system

Once identified a sub-sample of the coral was removed using sterilised forceps and scissors and placed into a 20 ml sample tube, along with a small cardboard label showing sample number, the latitude and longitude and depth from which the sample was taken. This was preserved in 99.5 % Ethanol to allow for genetic work once back in Southampton. The rest of the sample was then placed into a fume cupboard for 2 days to allow for drying and then placed in a bag with the sample number attached for future reference.

From the 56 samples taken during the course of the cruise 37 were successfully preserved, with the other 19 having to be disregarded due to loss of genetic material on the assent.

Preliminary results indicate that 8 species were sampled during the cruise (figures 25-34). However this can not be confirmed until the genetic work is complete.

Future work.

Once back on base the samples will be subjected to PCR analysis to both identify the species and to see the degree of genetic relatedness between members of the same species from different sites along the AVR. Coral distribution and percentage cover will be determined using the Isis videos.

During the dives a range of non coral organisms were also observed. These included Sea cucumbers, anemones, Sea urchins, fish, jelly fish, sea stars, a single octopus, squat lobsters and an unidentified crab species. The most common of these appeared to be the sea cucumber with 2 main species, one pink and one, being observed. Video analysis will also allow the determination of there percentage cover and allow the creation of a habitat map for the AVR area. Figures 35-43 show representative photos of these.

Figure 27- Possible Paragorgia species

Figure 28- Sea whip

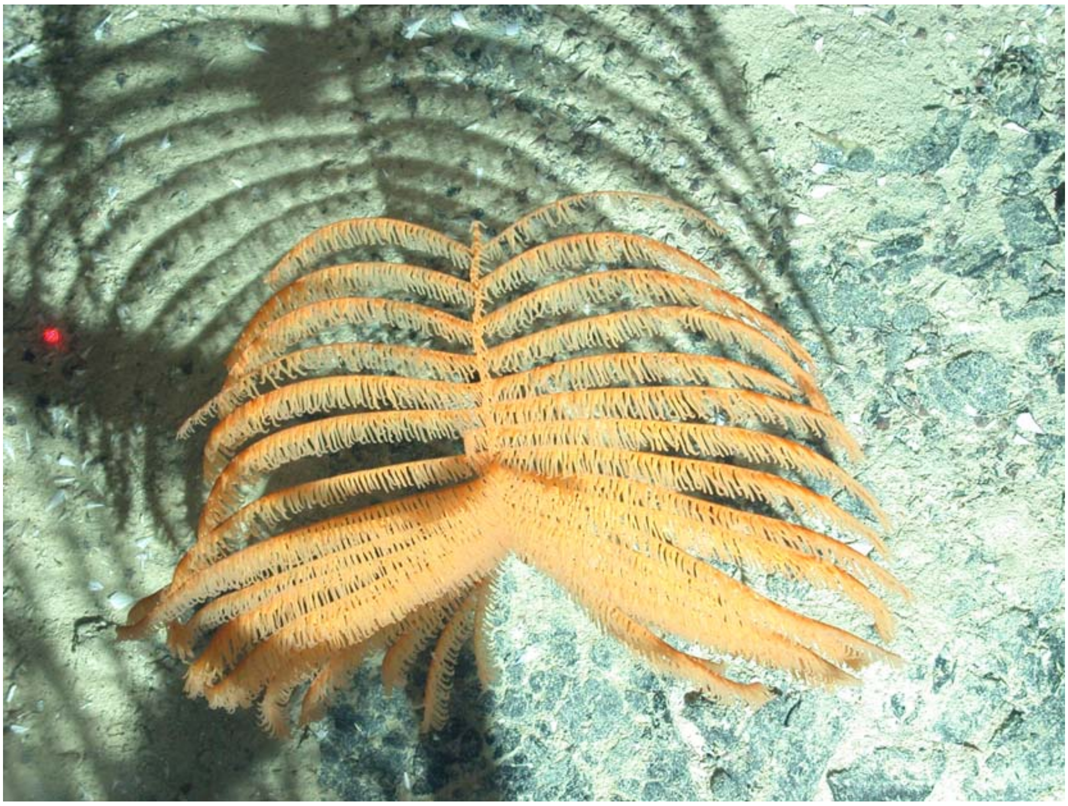


Figure 29. Sea pen species

Figure 30. Branching coral species

Figure 31. Second species of branching Coral

Figure 32. Sea pen species 2.

Figure 33- Narella species

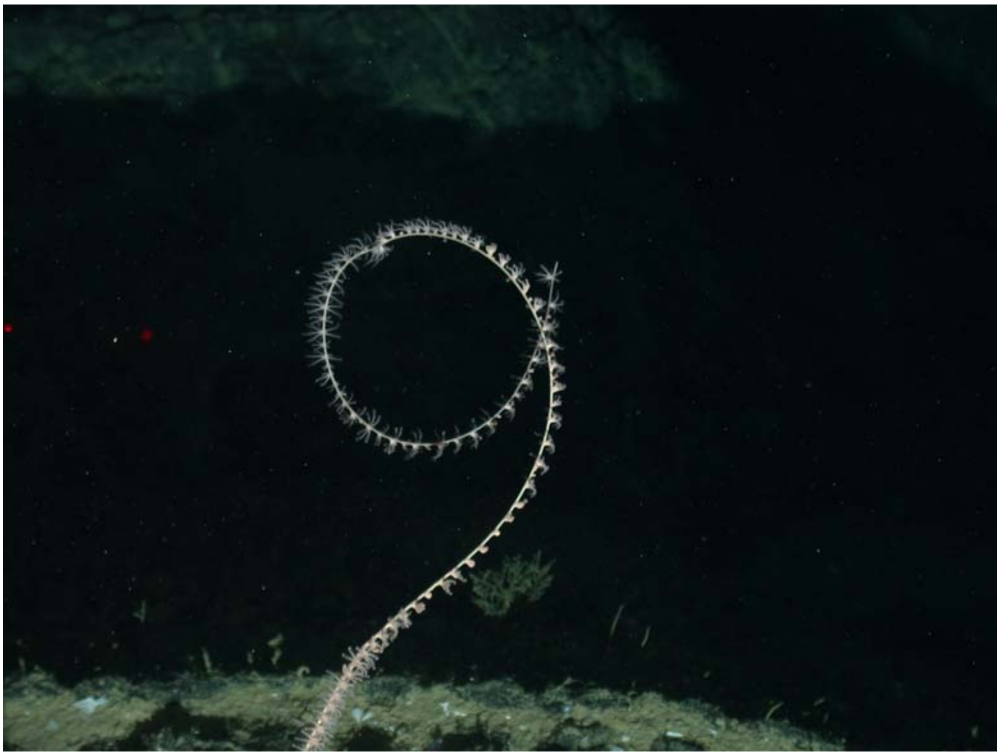


Figure 34- Whip coral

Figure 35-Octopus

Figure 36-Purple Sea cucumber

Figure 37-Pink sea cucumber

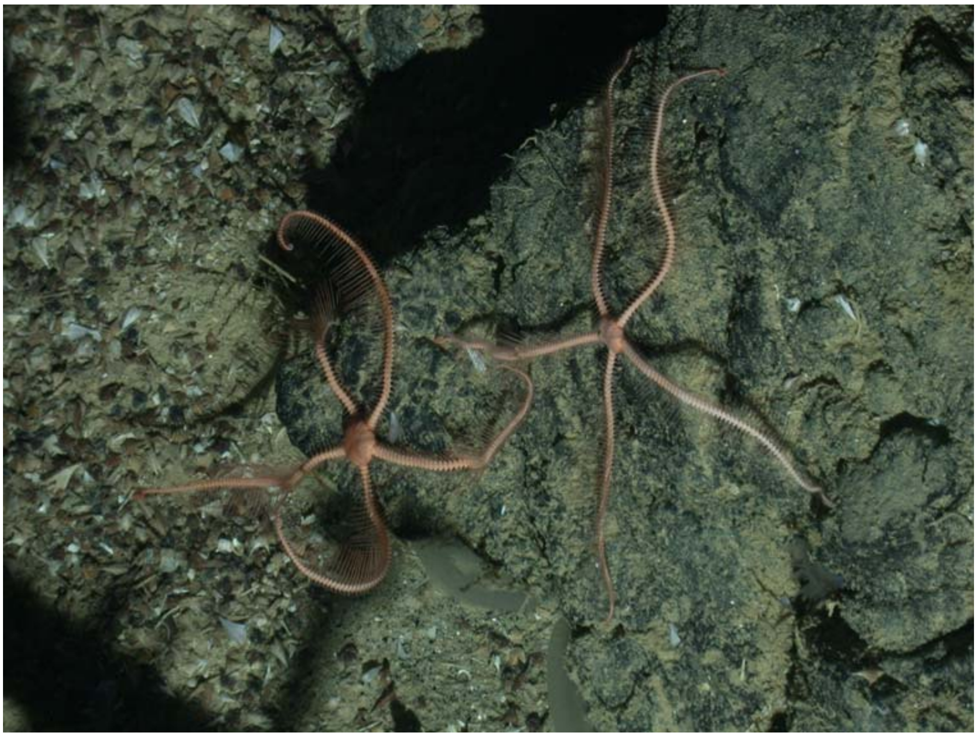


Figure 38-Brittle stars

Figure 39-Squat lobster

Figure 40-Unidentified crab species

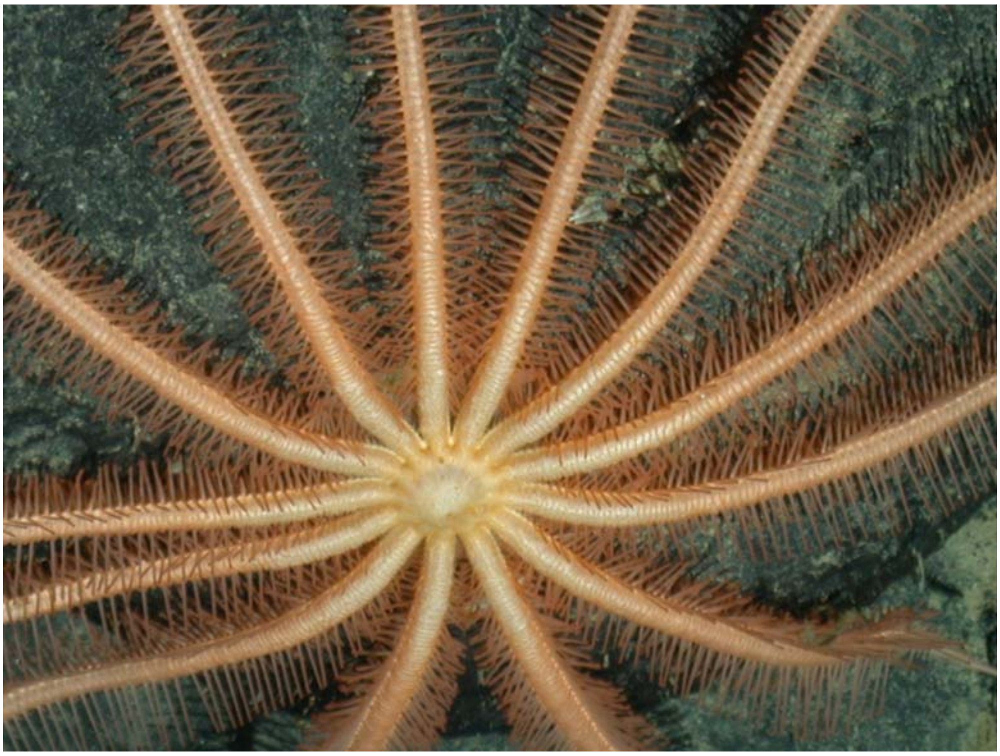


Figure-41 Feather star

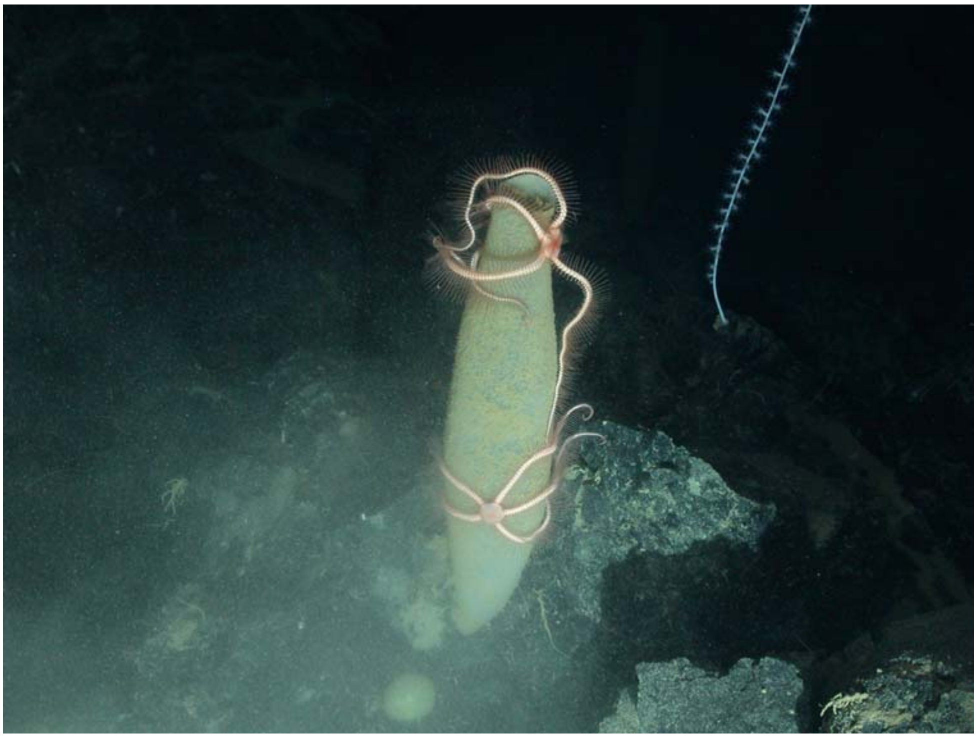


Figure 42-Sponge with brittle stars

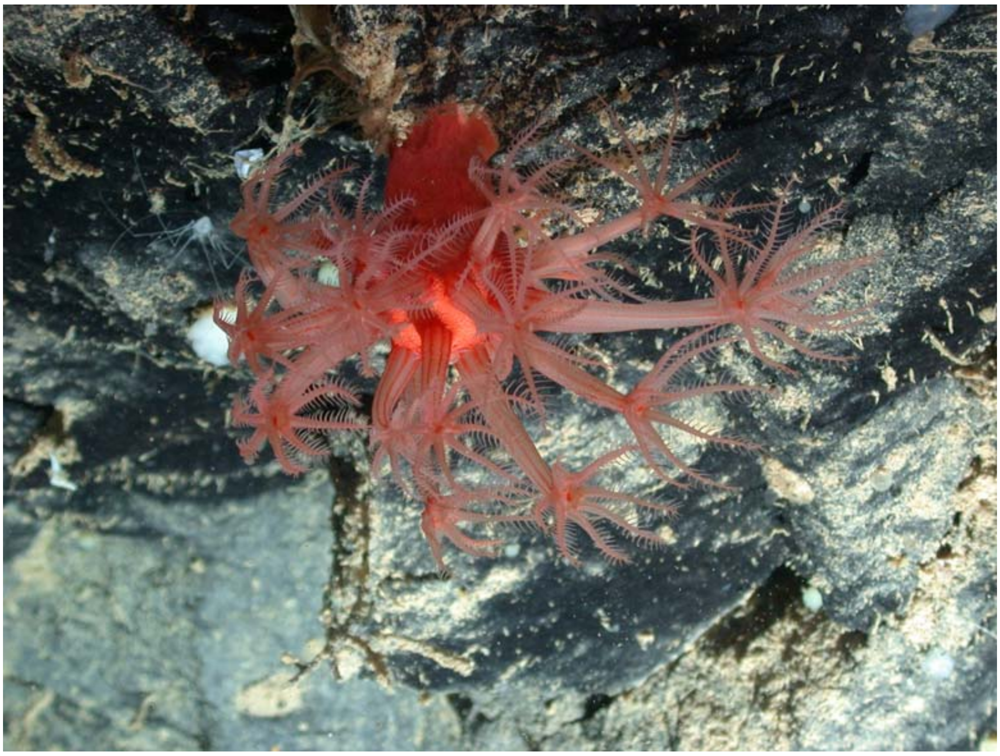


Figure 43- Pink Anemone

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MAPR operations

Bram Murton

Four MAPR (miniature autonomous plume recorders, Baker & Milburn, 1997) were supplied by Ed Baker of PMEL (Pacific Ocean laboratory, Seattle). These have been used on previous cruises and have proved very useful (e.g., Murton et al, 2006). Of the four, one MAPR was a new version that included an Eh sensor, to detect changes in reduction potential of the sea water. On this cruise, we had considerable trouble getting the MAPRS to operate.

Initially only two MAPRs were deployed. These were attached to a 100m – long pennant beneath the TOBI depressor weight. The pennant comprised 10mm diameter wire with a 150kg ‘V’ shaped depressor weight attached to the end.

Of these two MAPRs, only one operated, the other having stopped logging almost immediately. Nevertheless, combined with the TOBI LSS and CTD, we were able to detect two distinct regions of high nephels: one in the north east of the segment, and the other on the eastern side of the AVR, at 45°29’N; 27°51’W.

During down-time with the ROV, we deployed the two least unreliable MAPRs on the CTD wire, along with a 10kHz pinger and a heavy (150kg) chain attached to the end. These MAPRS were lowered to 2000m and then, with the ship moving at 0.4kts, hauled and veered at 40m per minute to within 50m of the sea floor. The pinger trace, and its bottom echo, were monitored using the EA60 echo sounder in passive mode.

Four ‘tow-yo’ surveys were made in this way: one east-west line in the north east of the segment, and two (a north-south and east west) lines centred on 45°29’N; 27°51’W. Finally a grid survey, with 2km long lines, spaced 200m apart, was conducted over the site at 45°29’N; 27°51’W.

In addition, MAPRs were deployed on ISIS. These proved useful, and were not affected by the ROV lights. However, they did detect the turbidity caused by the ROV’s thruster wash, and temperature changes of several hundredths of a degree Celsius when the ROV was stationary – probably caused by heat dissipation from the lights and power transformers.

The reliability issues with the MAPRs were partially rectified by re-soldering the battery contacts on the battery plate. These were found to have suffered mechanical damage over their life-time. The re-soldering solved most of the reliability problems, but we recommend the powering of the MAPRs be redesigned to ensure greater reliability in the future.

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HyBIS Operations

Bram Murton

The new, remotely operated TV-grab (HyBIS) was mobilised on the cruise for opportunistic trials. The vehicle is powered by a 1500V ac supply through the deep-tow cable and uses single-mode fibre-optics for communications.

On unpacking HyBIS from the container delivered to the Azores, it was found to have suffered significant damage in transit. All other items in the same container had also suffered damage, including the total destruction of several boxes of glasses and crockery destined for the galley. It was concluded that the container had been dropped during transit. The main damage to HyBIS was the destruction of its transport frame and slight bending of the main frame carrying the vehicle's transformer.

The vehicle was checked for any other damage, and then made ready for deck testing. Before connecting the power supply, the vehicle was earthed to the deck using an earth lead, and the area cordoned off.

On deck, all functions on the vehicle worked. However, there was a fault in the fibre-optic connection between the main lab. and the end of the deep-tow cable. This was eventually tracked down to poor connections at the winch slip-ring, poor connections in the deep-tow's termination bottle, and a poor external D G O'Brian connector. These were repaired as best they could be, although the D G O'Brian connector remained unreliable. After this, HyBIS worked reasonably well through the deep-tow cable on deck.

The vehicle was then readied for its first dive. This included checking the levels of compensation oil, making sure all blanking plugs were secured, all cable connections were tight, and that the vehicle was mechanically sound.

The first wet test was aborted at 10 m when the fibre-optic connection failed. This was again found to be a fault with the deep-tow termination bottle.

A second wet test was carried out, with the aim of reaching the sea floor at 2700m. Initially, all functions performed well. At 1700m depth, whilst taking turn wraps out of the cable using the HyBIS thrusters, there was a major power surge at the top-side transformer which tripped out the surge breakers. The vehicle was returned to the surface where it was determined that the vehicle's transformer had shorted. A mild (300 ohm) ground fault was detected, indicating water ingress into the transformer housing. No other short circuits could be found in any of the other pods, lights or motors.

After consulting HydroLek (the manufacturers of the HyBIS) it was decided to terminate further trials until the fault could be rectified. There was no obvious leakage of compensation oil. However, it is likely that the transformer housing was damaged (probably when the container in which HyBIS was transported was dropped), causing a break in the main 'o'-ring seal. This would have caused compensation oil to leak out and sea water to leak in – shorting the transformer.

Computing and Instrumentation

Chris Barnard

RVS LEVEL C System

IFREMER TECHSAS System

The IFREMER TECHSAS system is the primary data logger for all navigation, surface meteorology (surfmet), gravity, magnetometer and winch data. The TECHSAS software is installed on an industrial based system with a high level of redundancy. The operating system is Red Hat Enterprise Linux Edition Release 3.3 . The system itself logs data on to a RAID 0 disk mirror and also logs to the backup logger. The TECHSAS interface displays the status of all incoming data streams and provides alerts if the incoming data is lost. The ability exists to broadcast live data across the network via NMEA.

The storage method used for data storage is NetCDF (binary which is a self describing file and is OS independent) and also pseudo-NMEA (ASCII). The NetCDF data files are currently manually parsed through an application in order to convert them to RVS Format for data processing.

The TECHSAS data logging system was used to log the following instruments:

1) Applanix POSMV System (Converted to RVS Format as posmvpos, posmvatt, posmvsat)
2) Applanix POSMV System Heading
3) Kongsberg Seatex DPS-116 (Converted to RVS Format as dps116p and dps116s)
4) Chernikeef EM speed log (converted to RVS format as log_chf)
5) Skipper EM Speed Log (converted to RVS Format as log_skip)
6) Ship's Gyrocompass (converted to RVS format as gyronmea)
7) Simrad EA600 Precision Echo Sounder (Converted to RVS Format as ea600)
8) NMFD Surface-water and Meteorology instrument suite (Converted to RVS as sm_surf, sm_met and sm_light)
9) ASHTECH ADU-5 Altitude Detection Unit Converted to RVS Format as adu5pat and adu5pos)
7) NMFSS Cable Logging and Monitoring (Converted to RVS as winch)
8) Sondardyne USBL (Converted to RVS Format as USBL
9) LaCoste and Romberg Airsea II Gravity Meter (converted to RVS format as airseaii)
10) Marine Magnetics Seaspy Magnetometer (Converted to RVS Format as seaspy)

Techsas NetCDF to RVS Data Conversion

TECHSAS data have been included on the data archive in the standard rvs form using a piece of software used to make it compatible with the RVS ASCII data structure

An in house application was used to handle the conversion of NetCDF files to the RVS format. This was then parsed back to the data file and was processed as normal. These 2 new applications being ncvars and nclistit.

These new binaries require two environment variables in order to function:

$NCBASE – the base for the NetCDF binaries system, set to /rvs/def9

$NCRAWBASE – the base for the raw data files, set to /rvs/pro_data/TECHSAS/D321/NetCDF

The existing $PATH variable must also include the path to the NC binaries, the path /rvs/def9/bin was appended to the $PATH variable.

All Techsas data file names are in the format of YYYYMMDD-HHMMSS-name-type.category with the data/timestamp being the time the file was created by Techsas.

The files were each processed in the following way for this cruise:

nclistit 20060813-000001-gyro-GYRO.gyr - | titsil Gyronmea -

This output gyro data from TECHSAS in the listit output format that is then read in by the titsil application.

Data Processing

Applanix POSMV System

The Ships primary GPS System for scientific data and also part of the Dynamic Positioning system is the Applanix POSMV. The POSMV includes an inertial measurement unit capable of providing heading pitch and roll data to the bridge, logged by the Techsas system and displayed in the main lab. The POSMV data is also used by the ADCP systems in order to account for ships motion.

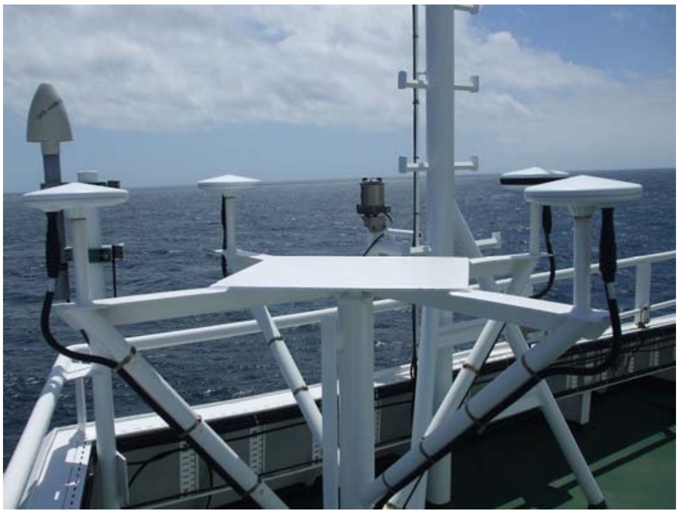
The Applanix IMU is located at the ship's centre point and is used as reference for all offsets for instruments on board the RRS James Cook The GPS antenna positions are held within the POSMV and the GPS position is corrected for the position of the MRU and so the GPS position that is recorded is the position of the MRU itself.

System Specifications

	Specification (With Differential Correction	During GPS Outages
Roll, Pitch Accuracy	0.02 º (1 sigma with GPS or DGPS	0.02 º
Heave Accuracy	5cm or 5% whichever is greater for periods of 20 seconds or less	5cm or 5% whichever is greater for wave periods of 20 seconds or less
Heading Accuracy	0.02 º with 2m antenna baseline	Drift less than 1 º per hour (negligible for outages < 60 seconds)
Position Accuracy	0.5 – 2m (1 sigma) dependant on differential correction quality	Ddegredation 2.5m (1 sigma for outages < 30s) <6m (1 sigma for outages < 60s)
Velocity Accuracy	0.03 m/s horzontal	

Magellan Ashtech ADU-5

This is a four antenna GPS system that can produce attitude data from the relative positions of each antenna and is used to correct the VMADCP for ship motion. The antenna array is located on the port side of the ship’s monkey island. The ADU-5 system worked reliably throughout the cruise with some gaps that are quite usual with this system due to the amount of calculations necessary and the roll of the ship causing bad satellite communication. No large data gaps are present. The ADU-5 forms part of the bestnav system which is an assembly of multiple GPS signals including the gyronmea and emlog stream in order to calculate the best possible position, speed heading pitch and roll of the ship.



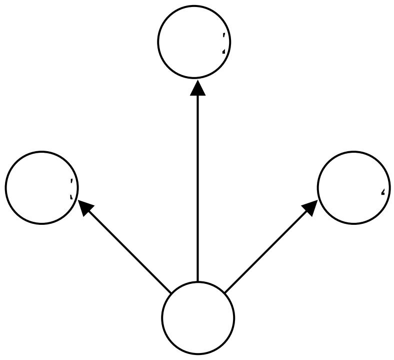


Figure 44. Here the ADU5 Platform on the Starboard Side. Black surrounded Antenna indicates AFT. This is the primary antenna which sits behind all 3 other antennas.

ADU5 offsets (in metres) with reference to Antenna 1 (used internally by ADU5 for HPR calculations):

Vector	X(Right Positive)	Y(Forward Positive)	Z(Up Positive)
1-2	0.000	1.203	0.010
1-3	-0.599	0.600	0.010
1-4	0.597	0.598	0.012

Antenna Position on James Cook From MRU (0,0,0)

Antenna	X (Positive Starboard)	Y (Positive Forward)	Z (Positive Up)
1	9.265	1.541	19.416
2	10.463	1.537	19.419
3	9.863	0.932	19.426
4	9.870	2.138	19.419

SeaTex DPS 116

This DPS116 is a GPS system that was installed primarily as a backup for the POSMV to provide information for the ships DP system for ships use which we now receive an output from. The Seatex is only configured to output a single GPGGA message which we record on the TECHSAS System.

The DPS 116 is located at the top of the ships Main mast.

Ship's Gyrocompass

The Gyronmea is a file that receives its data from the Ships gyro compass located in the Bridge Electronics Space. There are two such Gyros on the bridge and we are able to use either one of them as a source of heading. The selected Gyro is logged by the TECHSAS system and is used as part of the bestnav calculation.

Dartcom satellite imaging system

The Dartcom Satellite system was used during the cruise to produce weather images of the area around the ship. The Dartcom system receives its data from Fengyung CHRPT and NOAA HRPT satellites. Images were exported as JPEG's to the Dartcom directory on the Drobo storage system.

Chernikeef EM log

The Chernikeef EM log is a 2-axis electromagnetic water speed log. It measures both longitudinal (forward-aft) and transverse (port – starboard) ships water sped.

The EM log system was not showing the correct data following the last calibration attempt. The system has been highly unreliable since its installation within the ship and continues to be an ongoing issue that we are attempting to get support from the manufacturer for, however they are not so forthcoming.

Skipper Doppler Log

The Skipper Doppler log is the ship-fitted speed indicator mainly used by the bridge. It was repeated to the science systems due to the failure of the Chernikeef log to produce reasonable data for the first year and a half of the ships operation. The Skipper is continually logged as it provides good data quality and is a good comparison with the Chernikeef system.

Simrad EA500 Precision Echo Sounder (PES)

The EA500 was used purely for use with the 10Khz pinger for the deployments of the MAPRs on the CTD wire. The CRT screen, which has been an issue for sometime, was replaced during the MAPR survey as it was very difficult to see the lines on the screen. The Simrad EA500 is mounted on the Starboard drop keel.

Simrad EA600 Precision Echo Sounder (PES)

The EA600 Precision Echo Sounder is the ship's primary depth readout. The EA600 output is passed to TECHSAS and also to the green display screens in the main lab. The EA600 is mounted on the port drop keel.

Surfmet System

This is the NMFD surface water and meteorology instrument suite. The surface water component consists of a flow through system with a pumped pickup at approx 5m depth. TSG flow is approx 18 litres per minute whilst fluoriometer and transmissometer flow is approx 1.5 l/min. Flow to instruments is degassed using a debubbler with 24 l/min inflow and 10/l min waste flow.

The meteorology component consists of a suite of sensors mounted on the foremast at a height of approx 10m above the waterline. Parameters measured are wind speed and direction, air temperature, humidity and atmospheric pressure. There is also a pair of optical sensors mounted on gimbals on each side of the ship. These measure total irradiance (TIR) and photo-synthetically active radiation (PAR). The gimbals were removed and had new bearings installed at the beginning of the cruise prior to sailing.

The Non Toxic system was enabled as soon as we were far enough away from land and switched off during the port call in the Azores in order to protect the sea surface sensors from pollution which generally occurs close to land.

CASIX PCO2 System

This system is an autonomous pCO2 system developed by PML and Dartcom. I am not entirely sure of the full details of this system and advise contacting Nick Hardman-Muntford at PML for information. The system was run at the same time as the Surfmet system. The

System was cleaned on a weekly basis in order to remove fouling from the system as per the manual.

Sippican XBT MK21

The Sippican XBT system was used for 3 XBT Deployments. The system worked well and the data was good with very little spiking. The computer running the XBT Software had a problem with its power supply and so we had to move the XBT System into the main lab to a more usable computer.

Microg LaCoste AirSea II Gravity Meter S84

The Microg LaCoste gravity meter consists of a spring gravity sensor mounted on a gyro stabilized platform. The gravity meter is installed in the same location as the IMU at a location approximately (X=-0.5, Y=+1, Z=+0.5) from the IMU.

The gravity meter sends its data through RS232 and is logged on the TECHSAS System.

Specification:

SENSOR	
Range	12,000 mGal
Drift	3 mGal per month or less
Temperature Set point	46° to 55°
STABILIZED PLATFORM	
Platform Pitch	±22 degrees
Platform Roll	±25 degrees
Platform period	4 to 4.5 minutes
Platform Damping	.707 of Critical
CONTROL SYSTEM	
Recording Rate	1 Hz
Serial Output	RS-232
Additional I/O	Ambient Temp, Sensor Temp, Sensor Pressure
SYSTEM PERFORMANCE	
Resolution	0.01 mGal
Static Repeatability	0.05 mGal
Accuracy at Sea	1.0 mGal
MISC	
Operating Temperature	0°c - 40°c
Storage Temperature	-30°c to 50°c
Dimensions	71 x 56 x 84 cm
Weight	Meter 86KG, Unit 30Kg

Network Services

The network itself worked well without any issues. Ports required patching through to enable scientists to use the ports. One of the larger switches was moved from the Bridge Electronics Space to the computer locker. But many of the network ports have yet to be patched. This is due to lack of ports on board the ship patch them all at the same time.

The Wireless system, which failed during a previous cruise, was connected to a PC power supply as a means to test the Wireless system was still in working condition. The wireless system was used during the cruise and new power supplies are hopefully en route.

Data Storage

This cruise a new device was installed, known as a Drobo or Disk Robot. It was installed on the network and the Drobo 1 share was used by scientists to share data. The Drobo has a hot swap spare to ensure that the storage remains functional and secure at all times. The Drobo was backed up daily to LTO tape using SMB Tar on the Cook3 workstation.

The Level C data was backed up to LTO daily and included the TECHSAS mount from the TECHSAS data logger.

For any further information on this report please contact:

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Geographical Information System (GIS)

Tim LeBas

All the data from the cruise were collated and formatted for a GIS using ESRI ArcGIS version 9.2. A single map project **JC024.mxd** was created and has many grouped layers of data. The groups are (in order of viewing):

1. Biology samples (point data)
2. Rock Samples (point data)
3. ISIS vehicle tracks for dives (point and line data)
4. Ship tracks (point and line data)
5. TOBI vehicle tracks during acquisition (point and line data)
6. Bathymetry (EM120 and MS2000) (contour lines & grids)
7. Bathymetry from previous datasets and satellite altimetry (grids)
8. Magnetic data (grids)
9. TOBI imagery (grids)
10. EM120 Multibeam backscatter (grids)

Within the groups are subgroups and individual data layers. Following on from the numbering system above:

1. Biology samples data and have a hyperlink to a photo of sample in situ. Attribute data is available on each sample too – with fields of description and information pertinent to each sample.
2. Rock Samples are displayed 4 times so that each layer has a hyperlink. For each sample there should be 4 hyperlinks (Outcrop photo, General outcrop photo, Hand specimen photo and Rock collection video clip). It is suggested that any data searches are done on the 'Rock_samples_outcrop_photos' layer. Attribute data is available on each sample too – many fields of description and information pertinent to each sample.
3. ISIS vehicle tracks are divided into points (every minute) and lines (each a complete dive). Attribute data on the point data has date, time, and depth data.
4. Ship tracks are divided into points (every minute) and line (for the complete cruise). Attribute data on the point data has date, time, and main cable data. This cable data does <u>not</u> include the ISIS winch data.
5. TOBI vehicle tracks are shown as lines and points every 30 minutes on the GIS. The format of these data does not allow attribute data to be stored.
6. The main bathymetry group has the contours derived from the EM120 grid at intervals of 20m, 100m and 500m, together with a grid (at 50m resolution) of bathymetry values and a 3 band shaded relief image. The bathymetry group has a subgroup of the MS2000 bathymetry.

   The MS2000 bathymetry subgroup has the contours derived from the MS2000 grids from dive 87 and dive 91 at intervals of 10m and 100m, together with a grid (at 2m resolution) of bathymetry values and 3 band shaded relief images.
7. Bathymetry from other datasets are: EM12 bathymetry (collected in 1990's), a compilation bathymetry grid from echosounder data from the area, and satellite altimetry data (North Atlantic area) in grid and shaded relief imagery.

8. Magnetic grids for the area from several sources: TOBI magnetometer, ISIS dives 87 and 91 magnetometer and surface towed magnetometer. Magnitude and anomaly grids are included.
9. The TOBI data is divided into 3 areas (maps 1-3). Each area is then divided into 3 look directions: south looking, north looking and east-west looking. Imagery resolution is 3m. Data has been renavigated to fit the EM120 bathymetry.
10. The EM120 multibeam backscatter data is divided into 5 mosaics. Each mosaic was made to take account of the multiple coverage of the area. A single mosaic (emback) has been created of the whole area but may not be optimal in some parts.

The actual datafiles are generally held in two possible ways. For point and line data there are two formats: either in comma separated values (.csv) which is compatible with Microsoft Excel, or as a shapefile as used by ArcGIS. All the grid data is held in ERDAS Imagine (.img and the associated .rrd) format. Some of the grid data is also held as GMT (v3.4) grids (.grd).

The data was put on DVD and all data paths set to the relative position to the project file. To open the GIS double click the **jc024.mxd** file. ArcMap v9.2 must be installed and licensed (either by dongle or network server).

At time of writing (end of cruise) the DVD lacks some collection video files (dives 80 to 93). These can be added when they become available.

Appendix 1a: TOBI - A Brief Technical Specification.

Mechanical

Towing method	Two bodied tow system using neutrally buoyant vehicle and 600kg depressor weight.
Size	4.5m x 1.5m x 1.1m (lxhxw).
Weight	2500kg in air.
Tow cable	Up to 10km armoured coax.
Umbilical	200m long x 50mm diameter, slightly buoyant.
Tow speed	1.5 to 3 knots (dependent on tow length).

Sonar Systems

Sidescan Sonar

Frequency	30.37kHz (starboard) 32.15kHz (port).
Pulse Length	2.8ms.
Ouput Power	600W each side.
Range	3000m each side.
Beam Pattern	0.8 x 45 degree fan.

Bathymetry Sonar

Transmitter	Uses sidescan sonar.
Receiver	6 hydrophone arrays in 2 housings for each side.
Detection	Single and multi-phase.
Range	Up to 3000m each side.

Profiler Sonar

Frequency	6 to 10kHz Chirp.
Pulse Length	26ms.
Output Power	1000W.
Range	>50ms penetration over soft sediment.
Resolution	0.25ms
Beam Pattern	25 degree cone.

Standard Instrumentation

Magnetometer	Ultra Electronics Magnetics Division MB5L.
Range	+/- 100,000nT on each axis.
Resolution	0.2nT.

Noise	+/- 0.4nT.
CTD	Falmouth Scientific Instruments, Micro CTD.
Conductivity	
Range	0 to 65 mmho/cm.
Resolution	0.0002 mmho/cm.
Accuracy	+/- 0.005 mmho/cm.
Temperature	
Range	-2 to 32° Celcius.
Resolution	0.0001° C.
Accuracy	+/- 0.005° C.
Depth	
Range	0 to 7000 dbar.
Resolution	0.02 dbar.
Accuracy	+/-0.12% F.S.
Heading	
S.G. Brown SGB 1000U gyrocompass.	
Resolution	0.1 degrees.
Accuracy	Better than 1°, latitude < 70°.
Pitch/Roll	Dual Axis Electrolytic Inclinometer.
Range	+/- 20 degrees.
Resolution	0.2 degrees.
Altitude	Taken from profiler sonar.
Range	1000m.
Resolution	1m.
Additional Instrumentation	
Light back-scattering sensor	WET labs LBSS
Source	2 x 880nm LEDs
Detector	Solar-blind silicon light detector
Range	~10mg/l
Resolution	0.01% F.S., ~1ug/l

Appendix 1b: TOBI Data Format

This file contains information on the TOBI data structure and the calibration factors to apply to convert the raw digital instrument readings into real world units.

TOBI data structure

Every four seconds the data from all the instruments in the TOBI system are written onto disk in a 40kbyte block. The data are arranged in the structure given below with the relevant hex offsets. The original programmes were written in the 'C' programming language.

```
/* Structure of side-scan, profiler and telemetry storage block */
/***************************************************************/

struct buffer {                 /* Offset HEX  */
        char heading[48];             /*  0000     */
        int version;                  /*  0030     */
        int time;                     /*  0032     */
        int date;                     /*  0034     */
        int altitude;                 /*  0036     */
        struct position ship_posn;    /*  0038     */
        long magx[8];                 /*  0044     */
        long magy[8];                 /*  0064     */
        long magz[8];                 /*  0084     */
        int roll[8];                  /*  00A4     */
        int pitch[8];                 /*  00B4     */
        int height[8];                /*  00C4     */
        int gyro[8];                  /*  00D4     */
        unsigned int press[8];        /*  00E4     */
        unsigned int temp[8];         /*  00F4     */
        unsigned int cond[8];         /*  0104     */
        int water_path;               /*  0114     */
        int wire_out;                 /*  0116     */
        long lss[8];                  /*  0118     */
        byte empty[264];              /*  0138     */
        int port_ss[SSBLOCK];         /*  0240     */
        int stbd_ss[SSBLOCK];         /*  2180     */
        int prof[SSBLOCK];            /*  40C0     */
        int port_sw[SSBLOCK];         /*  6000     */
        int stbd_sw[SSBLOCK];         /*  7F40     */
        byte spare[384];              /*  9E80     */
        };                            /*  A000  40k */
```

Heading is a text character discription of the cruise and run, for example 'Urania 1998 Run#3'. A maximum of 48 characters may be used.

Version is the TOBI software version used during recording.

Time is the time of the writing of the data in IBM format.

Date is the date of the writing of the data in IBM format.

Altitude is the measured altitude of the vehicle above the seafloor.

Position is the GPS position of the ship. It is recorded as a structure with the following elements:

```
struct position {
        int long_degs;
        int lat_degs;
        float long_mins;
        float lat_mins;
};
```

Magx, magy and magz are the raw magnetometer readings recorded every 0.5 seconds, hence eight readings per record.

Roll and pitch are raw readings recorded every 0.5 seconds.

Height is not currently used.

Gyro is the raw gyro readings recorded every 0.5 seconds.

Press, temp and cond are the raw readings from the CTD unit recorded every 0.5 seconds.

Water_path is the time in milliseconds between the transmit pulse and the begining of the 200ms recording window for the profiler data.

Wire_out is the length of cable deployed in metres.

Lss is the reading from the light scattering senor on the vehicle.

Empty is space between the end of the instrument data and the begining of the sonar data.

Portss[] and stbdss[] are the sidescan data block arrays each 4000 samples long. Data are written from array location 0 at transmit to array location 4000.

Prof[] is the profiler data block array, 4000 samples long. The data is written from a buffer that is recorded over 200ms and then replayed over 4 seconds to reduce the effective sampling rate to one compatible with the other sonars. The offset in milliseconds to the start of the recording window is given by water_path.

Portsw[] and stbdsw[] are the swath bathymetry data block arrays each 4000 samples long. Data are written from array location 0 at transmit to array location 4000.

Spare takes up the remainder of the 40kbyte block.

TOBI Instrument Calibrations

Conductivity
Conductivity (mmho) = (reading/1000) - 2

Temperature
Temperature (degC) = (reading/2000) - 2

Pressure
Pressure (dbar) = (reading/10) - 5

Pitch
Pitch (deg) = reading/6.4
+ve pitch is vehicle nose down.

Roll
Roll (deg) = reading/6.4
+ve roll is vehicle roll to starboard.

Gyro
Gyro (deg) = (reading/10) - 10.1

Lss
Lss (volts) = (reading)*5.0/524288

Magnetics

Vx (volts) = (magx_reading)*2.5/524288
Vy (volts) = (magy_reading)*2.5/524288
Vz (volts) = (magz_reading)*2.5/524288

[B] = Km * [A][V]

Where:
B is the 3x1 matrix of corrected magnetic values in nT:

Bx
By
Bz

Km = 40,000 nT/Volt

A is a 3x3 matrix of manufacturer's calibrations:

0.9996297	-0.0057871	-0.0745943
0.0037991	1.0322001	0.0465985
0.0070859	0.0068992	1.0296533

V is a 3x1 matrix of manufacturer's offsets:

Vx - 0.0001508
Vy + 0.0002495
Vz - 0.0000618

Appendix 2: Log of TOBI discs recorded

M-O Number	File Name (*.DAT)	Time/ J. Day START	Time/ J. Day STOP	Comments / Run #	Profiler Roll #
2010	TOBI TOBIA TOBIB	11:53:58/146 14:26:56/146 14:39:30/146	14:18:12/146 14:31:46/146 04:18:42/147	START OF RUN#1 Portside swath not working – try power recylings. Came back to life after 10 hours, TOBI depth 2700m. No problems after that.	1
2011	TOBI	04:18:46/147	20:27:46/147		1
2012	TOBI	20:27:50/147	12:36:54/148		1
2013	TOBI	12:36:58/148	04:45:58/149		1
2014	TOBI	04:46:02/149	20:55:06/149		1
2015	TOBI	20:55:10/149	13:04:08/150		1
2016	TOBI	13:04:12/150	05:13:14/151		1
2017	TOBI	05:13:18/151	21:22:22/151		1
2018	TOBI	21:22:26/151	01:26:22/152	END OF RUN#1	1

Appendix 3: SM2000 Swath Files Summary:

SMB Files

Dive 87 (1514 files, 77.91GB)

```
-rwxr-xr-x + 1 isis  admin        1M Jun  8 01:07 Jun08,2008,01-07-27.smb [0]
-rwxr-xr-x + 1 isis  admin       49M Jun  8 19:49 Jun08,2008,19-46-50.smb [1]
-rwxr-xr-x + 1 isis  admin       49M Jun 12 20:59 Jun12,2008,20-55-22.smb [37]
-rwxr-xr-x + 1 isis  admin        8M Jun 13 08:04 Jun13,2008,08-01-48.smb [0]
-rwxr-xr-x + 1 isis  admin       49M Jun 13 08:48 Jun13,2008,08-47-09.smb [59]
-rwxr-xr-x + 1 isis  admin       47M Jun 13 10:12 Jun13,2008,10-10-54.smb [1]
-rwxr-xr-x + 1 isis  admin       49M Jun 13 10:18 Jun13,2008,10-17-00.smb [190]
-rw-r--r-- + 1 isis  admin        0B Jun 14 23:19 Jun13,2008,14-14-45.smb [983]
-rw-r--r-- + 1 isis  admin        0B Jun 14 23:19 Jun14,2008,12-10-53.smb [234]
```

Dive 91 (1560 files, 80.62GB)

```
-rwxr-xr-x   1 isis  isis       49M Jun 17 18:33 Jun17,2008,18-31-11.smb [10]
-rwxr-xr-x   1 isis  isis       49M Jun 17 21:14 Jun17,2008,21-11-48.smb [738]
-rwxr-xr-x   1 isis  isis       49M Jun 18 13:46 Jun18,2008,13-44-31.smb [140]
-rwxr-xr-x   1 isis  isis       49M Jun 18 16:56 Jun18,2008,16-54-52.smb [668]
```

Swath files summary:

MAB Files

Dive 87 (169 files, 67.8MB)

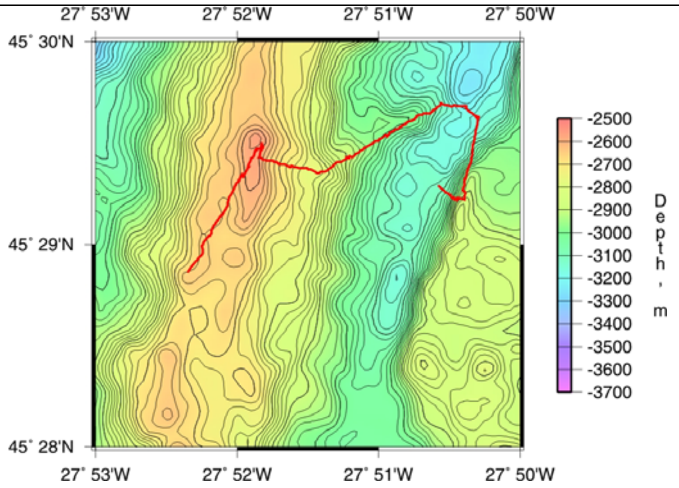
```
-rw-r--r-- + 1 isis  admin     995K Jun  8 20:00 Jun08,2008,19-49-02.mab [2]
-rw-r--r-- + 1 isis  admin     397K Jun 12 21:19 Jun12,2008,21-05-47.mab [3]
-rw-r--r-- + 1 isis  admin     397K Jun 13 09:00 Jun13,2008,08-47-38.mab [6]
-rw-r--r-- + 1 isis  admin      10K Jun 13 10:12 Jun13,2008,10-11-29.mab [0]
-rw-r--r-- + 1 isis  admin     398K Jun 13 10:29 Jun13,2008,10-17-19.mab [19]
-rw-r--r-- + 1 isis  admin     398K Jun 13 14:29 Jun13,2008,14-15-51.mab [10]
-rw-r--r-- + 1 isis  admin     395K Jun 13 16:43 Jun13,2008,16-30-10.mab [1]
-rw-r--r-- + 1 isis  admin     395K Jun 13 17:05 Jun13,2008,16-53-08.mab [36]
-rw-r--r-- + 1 isis  admin     394K Jun 14 00:39 Jun14,2008,00-27-10.mab [2]
-rw-r--r-- + 1 isis  admin     396K Jun 14 01:12 Jun14,2008,00-59-48.mab [36]
-rw-r--r-- + 1 isis  admin     397K Jun 14 08:42 Jun14,2008,08-29-09.mab [1]
-rw-r--r-- + 1 isis  admin     396K Jun 14 09:03 Jun14,2008,08-51-09.mab [15]
-rw-r--r-- + 1 isis  admin     398K Jun 14 12:24 Jun14,2008,12-11-40.mab [20]
-rw-r--r-- + 1 isis  admin     398K Jun 14 16:39 Jun14,2008,16-26-13.mab [1]
-rw-r--r-- + 1 isis  admin     398K Jun 14 17:01 Jun14,2008,16-48-47.mab [2]
```

Dive 91 (187 files, 67.9MB)

```
-rw-r--r-- + 1 isis  admin  385244 Jun 17 18:44 Jun17,2008,18-32-15.mab [0]
-rw-r--r-- + 1 isis  admin  407712 Jun 17 21:25 Jun17,2008,21-13-12.mab [15]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 00:44 Jun18,2008,00-32-20.mab [1]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 01:00 Jun18,2008,00-48-56.mab [14]
-rw-r--r-- + 1 isis  admin  406616 Jun 18 03:58 Jun18,2008,03-46-49.mab [1]
-rw-r--r-- + 1 isis  admin   10412 Jun 18 04:05 Jun18,2008,04-06-06.mab [0]
-rw-r--r-- + 1 isis  admin  407164 Jun 18 04:18 Jun18,2008,04-06-59.mab [13]
-rw-r--r-- + 1 isis  admin  404972 Jun 18 07:03 Jun18,2008,06-52-08.mab [1]
-rw-r--r-- + 1 isis  admin  406616 Jun 18 07:21 Jun18,2008,07-10-03.mab [14]
-rw-r--r-- + 1 isis  admin  406068 Jun 18 10:17 Jun18,2008,10-05-19.mab [1]
-rw-r--r-- + 1 isis  admin  405520 Jun 18 10:32 Jun18,2008,10-20-27.mab [13]
-rw-r--r-- + 1 isis  admin  406616 Jun 18 13:17 Jun18,2008,13-05-58.mab [2]
-rw-r--r-- + 1 isis  admin   73432 Jun 18 13:35 Jun18,2008,13-34-22.mab [0]
-rw-r--r-- + 1 isis  admin   23016 Jun 18 13:37 Jun18,2008,13-37-22.mab [0]
-rw-r--r-- + 1 isis  admin   41648 Jun 18 13:38 Jun18,2008,13-38-31.mab [0]
-rw-r--r-- + 1 isis  admin   19180 Jun 18 13:39 Jun18,2008,13-40-20.mab [0]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 13:57 Jun18,2008,13-45-17.mab [13]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 16:40 Jun18,2008,16-28-52.mab [2]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 17:06 Jun18,2008,16-55-15.mab [12]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 19:36 Jun18,2008,19-24-56.mab [1]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 19:53 Jun18,2008,19-41-45.mab [12]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 22:31 Jun18,2008,22-19-53.mab [1]
-rw-r--r-- + 1 isis  admin  407712 Jun 18 22:51 Jun18,2008,22-39-34.mab [12]
-rw-r--r-- + 1 isis  admin  407712 Jun 19 01:21 Jun19,2008,01-10-04.mab [1]
-rw-r--r-- + 1 isis  admin  407712 Jun 19 01:40 Jun19,2008,01-29-31.mab [11]
-rw-r--r-- + 1 isis  admin  406068 Jun 19 04:06 Jun19,2008,03-54-54.mab [1]
-rw-r--r-- + 1 isis  admin  406068 Jun 19 04:24 Jun19,2008,04-13-06.mab [11]
-rw-r--r-- + 1 isis  admin  405520 Jun 19 06:44 Jun19,2008,06-33-06.mab [1]
-rw-r--r-- + 1 isis  admin  406068 Jun 19 06:59 Jun19,2008,06-47-46.mab [5]
```

Appendix 4: Dive Summary Sheets

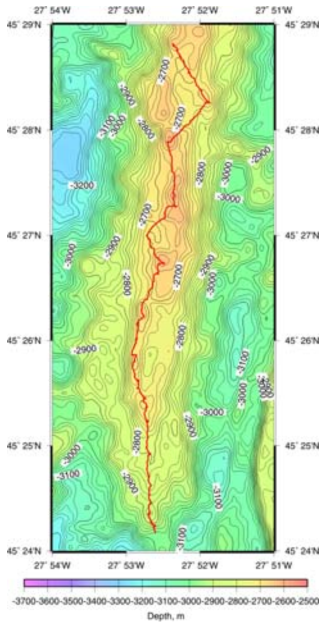
Report:	**Isis dive JC24-79**	
General position	SE flank and south-central axis of AVR	
	Start	End
Day/time	152/0816	153/0307
Latitude	45.4881	45.4810
Longitude	-27.8429	-27.8725
Depth	3123	2631
Tapes	JC24-79-T1	JC24-79-T7
DVDs	JC24-79-D1	JC24-79-D10
Rock sample	JC24-79-1	JC24-79-25
Bio sample	JC24-79-	JC24-79-



Objectives
Sample old rocks and stratigraphy of previous AVR(?) in median valley wall fault.
Sample intermediate age (?) rocks from MV floor.
Traverse and sample lateral spur up flank of AVR.
Traverse along crest of AVR to sample youngest (?) rocks and study volcanic structure.
Investigate summit graben (?)

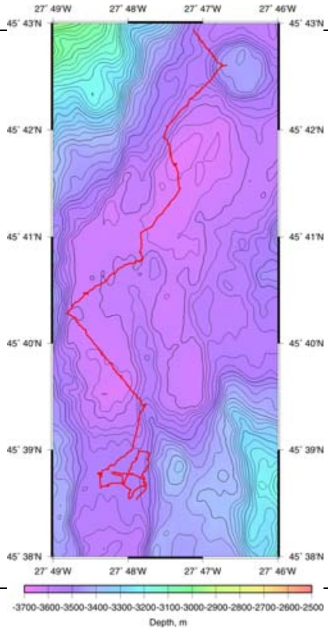
Observations
Extensive angular pillow breccias, massif flows and pillow lavas. Sediment cover with white patches
Fractured pillows in a vertical outcrop, fissures
Tabular pillow flows drooping downhill.
Many pillows with buds
Pillow size variations from 50 cm to>1m
Interlocking pillow flow
Contact between two clours of lava
Steep lava scarp with drain-out tubes
Lobate flow at low angle seafloor at the top of a terrace
Steep S-facing scarp with talus at the base, Steep SW-facing scarp, Age 2.5-3 Lobate pillow flow
Very fresh talus. Vertical wall, maybe fault breccia. Winnowed sediment. Highly elongated lava tubes
Pillow wall <10m wide with sheer drops on either side, Wall appears to curve around, >3/4 enclosed?
Talus on top of a ridge. Graben. Pillow with sed age 2-3. Elongated pillows, haystack
Very fresh lava. Scarp with broken pillows. Less sed on steep slopes. Eruptive fissure: pillows on both sides
A number of fissures 2-3m wide, 10m deep. Many pillows with buds. Collapsed pillows.

Report:	**Isis dive JC24-80 sampling dive**	
General position	SE flank and south-central axis of AVR	
	Start	End
Day/time	153/1110	154/1400
Latitude	45.4028	45.4803
Longitude	-27.8768	-27.8727
Depth	2971	2616
Tapes	JC24-80-T8	JC24-80-T17
DVDs	JC24-80-D11	JC24-80-D24
Rock sample	JC24-80-1	JC24-80-31
Bio sample	JC24-80-	JC24-80-



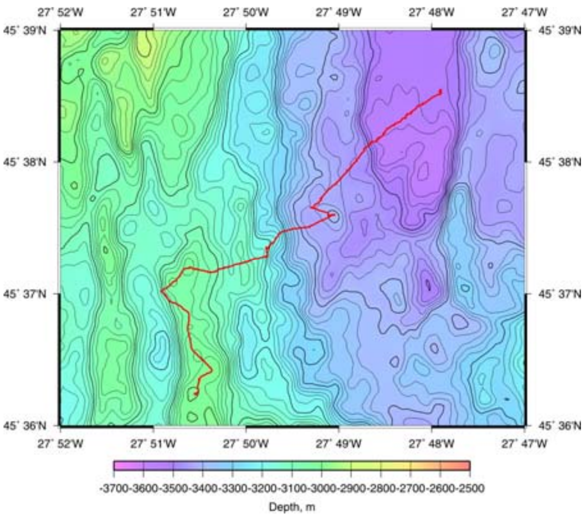
Objectives
Sample old (?) rocks at AVR end (WP 15-16).
Traverse along crest of AVR to sample youngest (?) rocks and study volcanic structure.
Investigate summit graben (?)
Complete traverse of southern AVR crest begun on dive 79.
observations
Unfractured pillows, haystack E. Scattered pillows in sed age=2.5-4. Small pillows on gentle slope.
talus ramp, no sed cover. Near vertical scarp with fractured pillows
In situ pillows on the top. Fissure with pillows outside haystack. Sed with few pillows sticking through. N/S fracture
Fissure with erupted pillows in sed terrain. Scarp, continuation of fracture. Two fissures merge
Pillow with sed cover age 4. Low lying lobate flows. Sed covered terrain
Scarp with in situ pillows, 10m. N-S fissures. Flat terrain sed cover
N-S fissure, pillows with little sed, age 1.2
Sed sheet flow on top of graben. Elongated pillow tubes. Sheet flow/lobate flow
Pillows 80% sed cover. Steep constructive slope to E. Total pillow outcrop, <20% sed
Tube pillows. Downslope 30 sed. Then 40-50% sed, then talus slope. Small fissure/ fault scarp
Lobate flow with sed covered collapsed pillows, continues. Knife-edge pillow ridge. N-S. fissure divides
More N-S fissure. Upstanding pillow tubes. More N-S fissures. Old pillows, variable sed cover
Fault scarp down W.. Up and down slopes. Talus with 10% sed, then talus on pillows >80% sed.
Meters deep cracks. Up and down plateaus and ledges. Few intact pillows, mostly sed.
Broken pillows and talus. N-S scarps, bulbous pillows, mostly sed

Report:	Isis dive JC24-81 sampling dive	
General position	High-backscatter lava flow adjacent to NE flank of AVR.	
	Start	End
Day/time	154/2240	156/0801
Latitude	45.7158	45.6422
Longitude	-27.7854	-27.7981
Depth	3517	3535
Tapes	JC24-81-T18	JC24-81-T29
DVDs	JC24-81-D25	JC24-81-D44
Rock sample	JC24-81-1	JC24-81-28
Bio sample	JC24-81-	JC24-81-



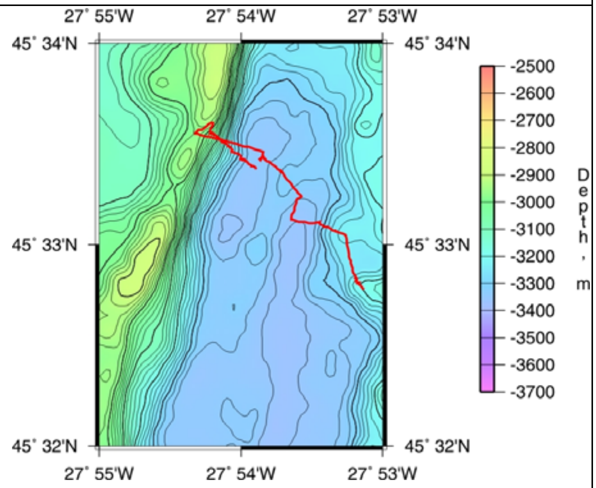
Objectives
WP 1-2: Sample old crust of MV floor and old (?) flat-topped volcano
WP 2-4: Investigate young sheet flow contact onto old sedimented crust
WP 4-7: Continue upstream (?) along sheet flow, crossing onto east flank of AVR
WP 7-9: Traverse south-east down AVR across sheet flow up to old MV wall
Observations
Large collection of bulbous pillows. Up scarp, more sed, less pillows. Up steep scarp, few pillows
Fissures trending 110 and 150, sheet flow under sed, sheet flow>1m thick
Rare pillows mostly sed. Descend down volcano flank, talus then pillows, large elongated tubes downhill
Flank collapse. Descend, to flat sed terrain with occasional pillows. More pillows at rare ridges.
100% sed. Fractured pillows at the top of a scarp. Altered basalt. Sheet flow on top of flow front, could be a dyke?
Extensive sed cover. Collapsed pillow or sheet flow? Broken flat lobate flows. Occasional outcrop at collapse pit
Pillows with only striations, no buds. Outcrop only at fissures. More of the same.
More pillows on reaching AVR. Pillows rock solid or total crumble. Sed 60-70%. Large flat lobate pillows.
Sed>90%, Pillows at base of AVR with some talus. Sed covered pillows
Dome of tabular stubby lava. Flat sed terrain. Sed covered sheet flow dome. E-W lava wall.
Sheet flow with occ pillow. Abundant pillows. Brown sed over cream coloured sed.
Old pillow flow over broken sheetflow. E facing pillow scarp. Sub-vertical fault scarp. Lava tubes on talus
Fissures parallel to main scarp. Intact pillows
5m wide pillow wall, steep fissures either side. Pillows fissured away from main wall. Pillows inside
fissure seem intact. Inside a fissure, 6m down: all pillows, maybe some talus near bottom. Numerous fissures
Scale dm to>10m width. Reddish-brown sed. Pillows on top of broken sheet flow. Some fissures have sed infill
Bacterial filaments? Occ outcrop. Track along fissure, it splits and run out
Curtain-folded sheet flow. More sheetflows. Tube pillows, sheets, skylights, collapse pits. Talus and sheet flow
Pillows, sed increase. Anhydrite? Old chimney? Vent bug?

Report:	**Isis dive JC24-82 sampling dive**	
General position	High-backscatter lava flow and adjacent NE flank of AVR	
	Start	End
Day/time	156/1531	157/1219
Latitude	45.6423	45.6040
Longitude	-27.7984	-27.8422
Depth	3529	2934
Tapes	JC24-82-T30	JC24-82-T37
DVDs	JC24-82-D45	JC24-82-D55
Rock sample	JC24-82-1	JC24-82-27
Bio sample	JC24-82-	JC24-82-



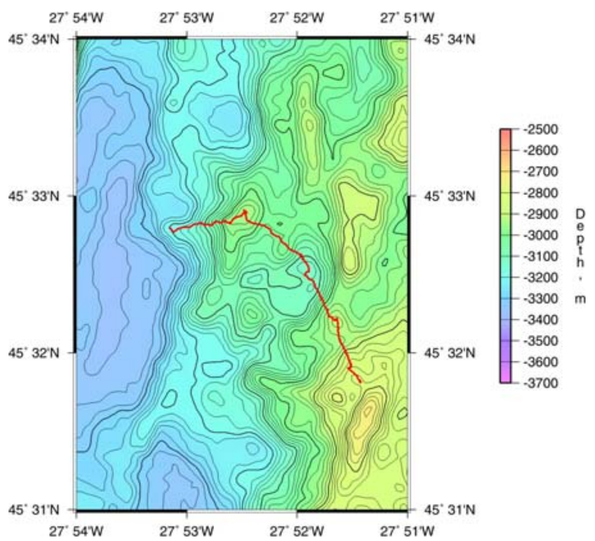
Objectives
Traverse south-west across sheet flow origin (?)
Crossing terraces up to top of AVR into axial graben
Observations
Heavily sed piloow terrain. Sheet flow collapse area. Burried sheet flow, pillow outcrop
Lose pillows, mushroom pillow. Some steep slopes, 100% sed on flat areas. Occ pillow associated with
fissures. Down vertical SW facing wall. Climb subvertical talus wall. Shelf sed with occ pillow
Less sed on slopes. Scarps and shelves, round pillows. Flat sed terrain with fissures
Flow front with budded pillows. Pillows with sed caps
Pillow tubes, flat pillows on top. Flow front with less sed. Another flow front
Climb pillow wall, elongated lavas. Small haystack on top. Decorated pillows and lava flowing out of broken pillow
Bulbous pillows, elongated on slope. Sed-covered talus at slope base, thick sed on top
Major constructional scarp. N-S fissures in pillow lava field
Talus at next climb some sed, none near top. At top sed covered talus? Climb further. Pillow lava at scarp edge
Rubble front with sed on top. Blocky outcrop, not talus.
Pillows. Down pillow slope, then talus, then talus with sed
Pillow wall, subvertical W facing. Crossing fissures. Black material on sed, glass?
Pillows with sed cover 50-70%.. Line of pillows, then covered in rubble,\then sed
Extensive sand with black cover, occ fissure, some pillows, some collapsed
Trapdoors, sheet flows. Sed cover, fissures, mostly sed
Top of slope, pillows and sheet-like pillows

Report:	Isis dive JC24-83 sampling dive	
General position	West central flank of AVR and adjacent MV floor and wall	
	Start	End
Day/time	157/2040	158/0606
Latitude	45.5563	45.5463
Longitude	-27.8982	-27.8855
Depth	3349	3139
Tapes	JC24-83-T38	JC24-83-T41
DVDs	JC24-83-D56	JC24-83-D60
Rock sample	JC24-83-1	JC24-83-11
Bio sample	JC24-83-	JC24-83-



Objectives
WP 1-2: Investigate and sample young (?) sheet flow on MV floor
WP 2-3: Climb west up axial valley wall and sample older lavas there
WP 3-5:Return to sheet flow, cross apparent age contact W of AVR crossing terraces
WP 4-5: Cross little ridge of hummocks towards spur on AVR flank

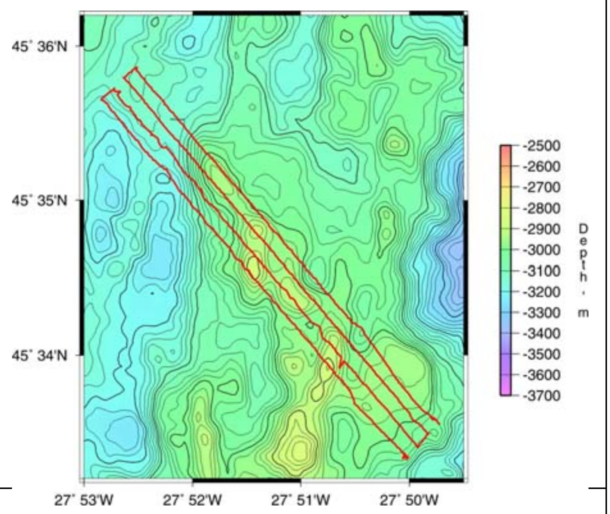
Observations
Sed with few protruding pillows, 100% sed then talus slope. Talus on sed. Fault breccia. Vertical wall
Indurated sed. Sed around pillows. Fractured and broken pillows. Fault scarp. Pillows in wall, steep
Down slope. Flow front, fissures. Broken and fractured pillows. Low flow front ~1m
N-S scarp, facing W Many more fissure/fractures N-S. large pillows, some fissures are filled with pillows
Some cracks only cm, others >m. On and off sed. Rubble flow front
Constructional pillow front. 20m scarp with pillows on the ledge. Lava stalagtite over old pillows

Report:	Isis dive JC24-85 sampling dive		
General position	West central flank of AVR		
	Start	End	
Day/time	159/1030	160/0035	
Latitude	45.5465	45.5303	
Longitude	-27.8859	-27.8571	
Depth	3140	2784	
Tapes	JC24-85-T42	JC24-85-T46	
DVDs	JC24-85-D61	JC24-85-D67	
Rock sample	JC24-84/5-1	JC24-84/5-18	
Bio sample	JC24-85-	JC24-85-	

Objectives
Continue Dive 83 up spur on AVR flank
Cross to main mass of AVR
Investigate central graben & crest of AVR

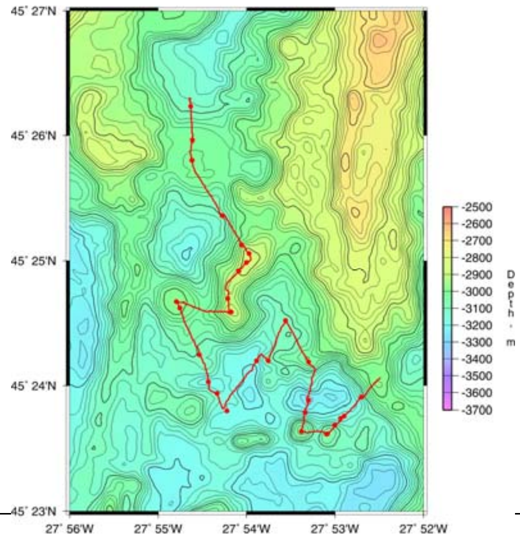
Observations
Pillows and fragments in sediments. Some pillows with sed cap, mostly smooth with few buds
Pillow tubes wit numerous buds. Top of flow fronts: more sed cover, shorter tubes
Pillow rubble, talus slope, then pillow wall, then pillow tubes, >50% sed cover. Total sed on top shelf
Pillow rubble, talus slope, pillow wall, then pillow tubes, mostly sed cover with pillows poking through.
Total sed on top shelf. Very bud-rich pillows
Flat terrain with knobbly pillows 50% sed cover. Sed plain with occ knobbly pillow
Talus ramp, no sed. Shelf, then another talus ramp, sparse pillow
Climbing NE facing slope, pillows emerging from rubble. NE facing pillow tubes
Vertical face with fractured pillows and intact lava tubes over them
Truncated tubes and pillows, sed cover 60%. Talus chute, fractured pillows in fault wall, vertical wall
Fractured flattened pillows near the top. Top is sedimented with occ pillows.
A few ‘drips’ of fresh pillow tubes sticking out of the wall, extruding over sed. Sed <30%
Irregular slope, dark patches on the cream sed. Fissure with pillow outcrop. Talus wall with descending tubes
Undulating terrain >80% sed
Talus slope, variable sed cover 30-80%, then total pillow wall, ledge. Then talus slope, then talus with sed
In situ pillows and flattened pillows. Downhill on steep talus, pillow tubes and pillows
Spotted a trailing cable: abort dive

Report:	**Isis dive JC24-87 MS2000 survey dive**	
General position	Northwest flank of AVR	
	Start	End
Day/time	164/0630	166/1920
Latitude	45° 33.360’	45° 35.835’
Longitude	-27° 52.82’	-27° 49.626’
Depth		
Tapes		
DVDs		
Rock sample		
Bio sample		



Objectives
SM2K and magnetometer survey
Observations
8.5 hours per line surveyed 4 lines in total, mostly at 0.4 kn. Occasionally 0.5 kn but ROV
pitches and rolls too much.
ROV pitch and roll is related to ship movement and can be reduced by cable parameter optimisation
But not durably
Survey at ~100m above bottom, spaced at 180m

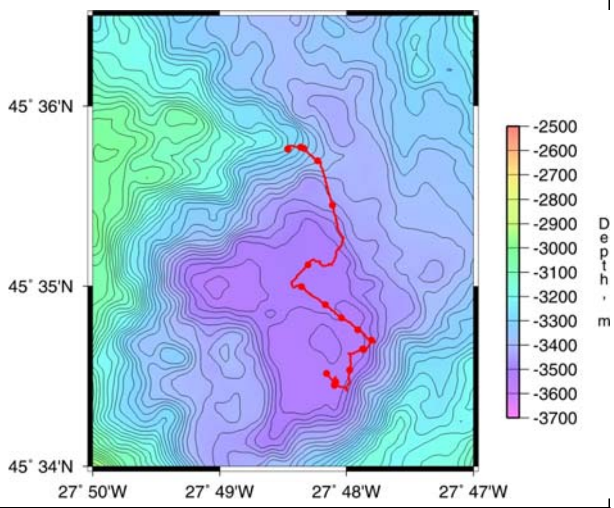
Report:	Isis dive JC24-88 sampling dive	
General position	Highly magnetic southwest tip of AVR	
	Start	End
Day/time	166/2330	168/0246
Latitude	45° 26.301	45° 24.06
Longitude	27° 54.638	27° 52.50
Depth	3121	2961
Tapes	JC24-88-T47	JC24-88-T56
DVDs	JC24-88-D68	JC24-88-D81
Rock sample	JC24-88-1	JC24-88-31
Bio sample	JC24-88-33B	JC24-88-33B



Objectives
Investigate low backscatter regions of median valley floor including flat-topped seamount
Investigate medium backscatter to high b/s hummocky seamount at magnetic high
Sample mid-backscatter flat-topped seamount
Traverse areas of high, mid and low backscatter in region of magnetic highs
Sample very tip of AVR

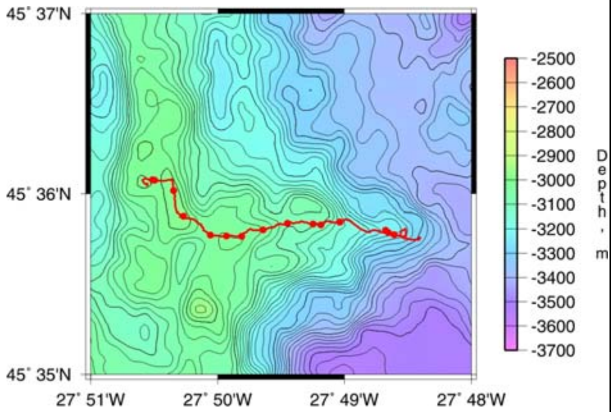
Observations
Fully sedimented with thin cover of black material, bioturbation obvious.
Frequency of pillow outcrop increasing. . Pillow outcrop in steep sediment scarp on the side of the seamount
100% sed. Isolated rock fragments and the odd pillow. Top is 100% sed cover. Pillows emerge on the downlope
A line of pillows, then sed again. Very few pillows. Talus chute. Jumbo lava tubes on scarp: constructional
Pillows and shattered pillows on slope, top is covered with sed and flat pillows. Lobate flow, skylight
Pillows with buds. Rubble flow over pelagic sed. Sed covering sheet flow, skylights
Extension cracks; inflation cracks. Platy outcrop: lava tube, collapsed roof. Nearly 100% sed cover,
exposure only along cracks.
Smooth pillows but isolated. Collapsed tube, climbing 60 degree slope, fissures.
Sed cover both up and down slope
Pillowed scar of pillows with tubes . large collapse pillow sheet. Lobate lava buried in sed
Head for small peak. Drained pillows, small haystack. Pillow cascade down stepped slope
Lava tubes radiate from summit
Pillow field with 60% sed, about 30 degree slope. Scarp N-S near top
Minimal talus downslope, Pillows with numerous buds
Pillows and tubes, many broken, 50% sed Descending steep slope with extensive pillows and tubes
Climb: pillows and tubes , 40% sed At the base 100% sed, next slope talus, then 100% pillows. Very steep
Pillow cascade over stepped slope, Sed at summit and haystack

Report:	Isis dive JC24-89 sampling dive	
General position	Lava flow and lateral spur at NE flank of AVR	
	Start	End
Day/time	168/0825	168/2246
Latitude	45° 34.505	45° 35.760
Longitude	27° 48.172	27° 48.461
Depth	3523	3274
Tapes	JC24-89-T47	JC24-89-T56
DVDs	JC24-89-D68	JC24-89-D81
Rock sample	JC24-89-1	JC24-89-19
Bio sample	JC24-89-33B	JC24-89-33B

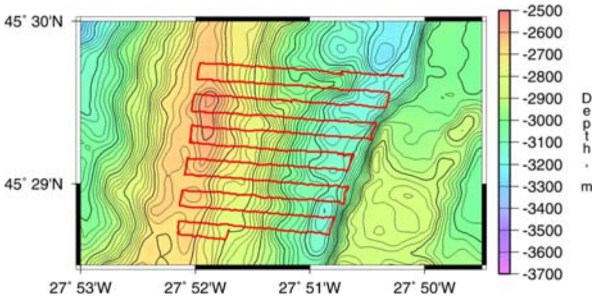


Objectives
Investigate flat lava flow on median valley floor, contacts, and possible flow sources
Investigate lateral spur of AVR
Observations
Sed 60%, with pillows and tube outcrop. Slow descend but regionally flat. Pillows on top of sheet flow
Pillow wall with a number of lava tubes, some open and apparently spilling lava pillows.
Lava drips and curtains from a tube roof. Scarp 10m high consists of more collapsed tubes and pillows
Scarp fault probably pre-syn-post volcanic. Scarp ~N-S, W facing.
Top shelf is sedimented and with numerous cracks, some collapse features
Flat sed covered terrain, Pillows stick out of sed wall, 90% sed. Continuous slope with N-S fissures
Few fissures have a few dm vertical drop . Climb another pillow wall.
Vertical dyke with complex structure. The very centre 10cm has vertical foliation and is partly open.
Either side is horizontally foliated with drag folds on the edges, Then vertical foliation again further out
are steeply inclined foliations. At the top the foliation folds over downwards and may feed a lava lobe.
At the top of the scarp a fissure is located right above the dyke. Also the roof of a lava tube with pillows on top
Shelf is sedimented with pillows along the N-S fissure. Follow sed shelf along scarp.
Tabular blocks buried in sed. Pillow lavas on topo high. Thickly sed undulating terrain, blisters of lobate lava
Curtain-folded blocks in chaotic pile with lava tubes. Expansion cracks in lava sheet with pillows coming out
Cracks in bulges in the sed terrain, several haystacks. Tabular shells/blocks, collapsed lobes
Thick sed with occ pillow. Obliquely upslope, pillows more equant, few tubes, then 100% sed
Climbing fault scarp mostly intact pillows, few fractured. Top of scarp: 100% sed
Sed and scattered pillows with bids. Steady climb: less sed, down to10-20%
Long tubes with no ornamentation and pillows

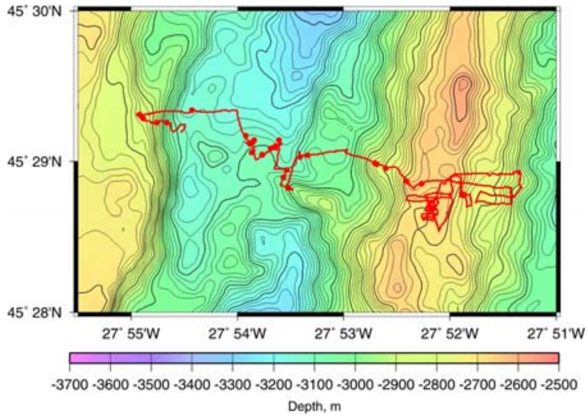
Report:	**Isis dive JC24-90 sampling dive**	
General position	Lava flow and lateral spur at NE flank of AVR (continuation of Dive 89)	
	Start	End
Day/time	169/0530	169/1522
Latitude	45° 35.757	45° 36.143
Longitude	27° 48.403	27° 50.369
Depth	3298	2974
Tapes	JC24-90-T59	JC24-90-T62
DVDs	JC24-90-D90	JC24-90-D95
Rock sample	JC24-90-1	JC24-90-16
Bio sample	JC24-90-33B	JC24-90-33B



Objectives
Investigate lateral spur of AVR
Sample AVR crest
Observations
Pillow slope, 35 deg, dipping SE pillows and fragments. Dipping pillow tubes, haystack on top
Thick sed on SE slope. E-W fissure with exposed pillows with buds, many E-W fissures in pillow lava.
40% sed cover. Steep pillow slope. 80-90% sed cover. Pillow wall after sed shelf. Pillow wall <30% sed
Pillow fragments and talus, constructional slope, 50% sed. To top of knoll. Down and up new flow
Again, down and up new flow, pillows with tubes near top. Profusion of protrusions on pillows, some tubes
Some talus on slope. Top of hummock intact pillows and talus, 20% sed. Pillow generations visible
Resume pattern up the ridge: talus at lower slope then pillows then pillows and tubes. E-W fissures
Steep pillow wall. Winnowed black sand between pillows. Sed maybe actually between pillows:
Pillows intruded into sediment. Pillows extensively decorated with buds. Flatter pillows near the hilltop
Pillows decorate fissures. Inflated big pillows, collapsed lobes.
Scoriaceous pillow
Edge of summit area, less sed, bulbous pillows, lobate flows
2m fissure at 310 deg, more fissures same orientation. Almost total sed cover
Black material covers the whole of the sedimented summit

Report:	**Isis dive JC24-91 SM2K survey dive**		
General position	SE flank of AVR		
	Start	End	
Day/time	169/2116	171/0754	
Latitude	45.494°	45.847°	
Longitude	27.837°	27.862°	
Depth	3024	2776	
Tapes	JC24-91-T63	JC24-91-T64	
DVDs	JC24-91-D96	JC24-91-D96	
Rock sample	None		
Bio sample	None		
Objectives			
SM200 and magnetometer survey hunt for hydrothermal vent!			
survey hunt for hydrothermal vent			
Observations			
At the end of the pattern, investigated a 0.2 C temperature fluctuation in SW corner.			
A small mound appeared in the bathymetry			
Very fresh pillows, no hydrothermal activity			

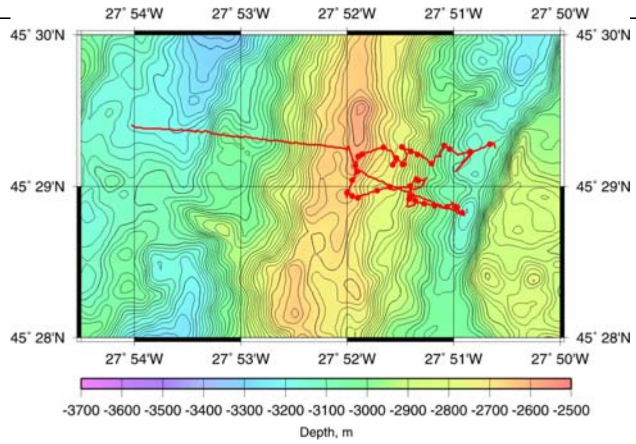
Report:	**Isis dive JC24-92 sampling dive**	
General position	West median valley wall and west southern flank of AVR	
	Start	End
Day/time	171/1329	173/0425
Latitude	45° 29.201	45° 28.863
Longitude	27° 54.527	27° 51.942
Depth	3110	2711
Tapes	JC24-92-T63	JC24-92-T76
DVDs	JC24-92-D96	JC24-92-D117
Rock sample	JC24-92-1	JC24-92-26
Bio sample		JC24-92-51B



Objectives
lava stratigraphy exposed by valley wall fault
Possible contact between sheet and pillow flows at base of AVR
Investigate possible sheet flows exposed in fault scarp at base of AVR
Complete traverse to crest of AVR
(Following forced extension due to weather): visual survey around hydrothermal plume locations
(Following forced extension due to weather): mini magnetic survey over AVR crest

Observations
Talus and pillow fragments 50% sed, then 100% sed. Flat terrain, 100% sed. Up scarp ta 22 deg
Large pillow slabs and rubble. Sharp ridge with needles. Steep sed slope, occ pillows
Talus ridge and another pinnacle. Blocky sheet flow. Talus and sed cover. Pillow ourcrop, then hummocky sed
WSW pillow scarp, following 280deg scarp, then 310 deg fissure. Blocky scoriaceous flow. Then 100% sed
Consecutive steps ~3m. Vertical wall, rubble at the bottom. Many faulted pillows, some intact.
Talus, pillows, sheetflow, pillows,talus, sed. Multiple coloured layering in sediment, exposed in contorted gullies
Hardly looks tectonic. Sed eroded to expose undisturbed pillows at the bottom, maybe4-5m down.
Sed with fissures, some with pillow decoration. N-S fault pillow scarp, 10m deep chasm, pillows at bottom
Sed cover. Repeat pattern. Scarp top at 40m. Vertical pillow wall, sed pillow wall. Glassy bud pillows
Vertical scarp 50m. Dead tubeworm patch 2m square. N-S fissure. Pillows and lobes 50% sed cover.
Descend fault scarp and up the next. Pillows with 30% sed. Some elongated pillows. Payload max reached
But no recovery because of weather, Visual reccy. Pillows downslope, Search pattern in hydrothermal prospect.
Pillows and tubes with varying sed cover. Constructive pillow slope. Haystack on top of gentle top of hill
Repeat of this terrain: rubble/talus with sed cover on lower slopes, pillows higher up, pillow tubes over pillows
Reduction in slope, more sed cover, occ pillows and deflated pillows, hatstack on top. All the way to top of AVR
Fissures N-S. Descend to bottom of graben, intact pillows at the top, faulted further down. Fissure with 1m E
Downdrop.Up slope, haystack on top. Down slope. Collapsed sheetflow feeder. Converging fissures, one faulted
The other intact pillows.

Report:	**Isis dive JC24-93 sampling dive**	
General position	Eastern flank of AVR over SM2000 survey	
	Start	End
Day/time	171/1329	173/0425
Latitude	45° 29.264	45° 29.395
Longitude	27° 50.608	27° 54.006
Depth	3119	3083
Tapes	JC24-93-T77	JC24-93-T84
DVDs	JC24-93-D117	JC24-93-D128
Rock sample	JC24-93-1	JC24-93-38
Bio sample		JC24-93-51B



Objectives
Two traverses up AVR flanks over area of SM2000 survey
Investigate 5-6 terraces in AVR flank
Investigate and compare semi-parallel E-W lines small volcanoes on AVR flank
Compare volcanoes *within* these E-W lines
Obtain a 100 m altitude magnetic profile over west flank of AVR
Observations
Thickly sedimented pillow features. Gentle downhill, climbing sed slope, few pillows
Pillow tubes, then pillows with sed, upslope: drained pillows, small haystack. Downhill pillows with sed cover
Talus ramp near bottom. Uphill, talus, pillows, tubes over pillows, small haystack pinnacle, deflated
Pillows around. Downslope, pillows and some elongated pillows. Knobby pillows flowing downhill.
Uphill talus ramp, sed slope, pillows on steeper slope, small scarp near top. Downslope: pillows then talus
Pillow outcrop. Tubular pillows from haystack, base of slope is rubble. Talus chunks have weathered interior
Talus and sed., then pillows and tubes. Blocky lava. N-S fissure, climb fissure wall is fault scarp.
Fractured and intact pillows in scarp. Flattened pillows near top. Normal pillows away from top with plenty
Buds, also tubes with abundant buds. N-S fissures
Scarp, sed slope with brown patches. Pillow basalt near scarp top. 100% sed. Large N-S fissure, some fissures
are sed filled. Knobbely pillows with sed cover. 100% sed cover with occ pillow. Up to top of scarp.
Fe-stained pillow frags, altered rock. N-S fault dissects small volcano, downslope elongated tubes.
Up scarp of pillow sections. New pillow tubes over older sedimented pillows. NE dipping fissure, summit haystack
Climbing, flattened pillows and tubes 30%sed, pillow jumble, steep W wall of fissure turned into a pillow slope
Up N-S fault scarp, pillows with buds. Small tumulus with flattened tubes emanating. Further upslope
Pillows, 30% sed, then pillow wall, Flatter to top, flattened pillows and collapse structures, Follow deep fissure
205 deg N several m across .10m deep, followed across the entire summit, disappeared at the N scarp
Downslope N sed in valley, up next seamount: talus, pillows, tubes deflated tubes at summit.
Maggy survey E-W