Cruise report JC083

Marine Record of Hazardous Events offshore from an Island Arc Volcano; Montserrat, Lesser Antilles

1-8 March 2013

1. ABSTRACT

The cruise was located offshore Montserrat and Antigua in the Lesser Antilles. The first aim was to field test a new vibracorer module that is added to the ISIS Remotely Operated Vehicle. A series of 12 ROV dives (numbered 208-219) established that the mechanical part of the system that lowered and retracted the corer worked very well. However, further work is still needed as the vibrator motor may be underpowered. This is the subject of ongoing work with colleagues at the Monterey Bay Aquarium Research Institute, who have a fully operational ROV-vibracorer system. The longest core recovered by the current ISIS-vibracorer system is 45cm, and this core will help to date the largest blocks in a major volcanic flank collapse deposit. The second aim was to understand the marine record of potentially very hazardous events around this island arc volcano. This includes the marine record of an extremely violent pyroclastic surge that occurred in 1997, during the 1995-to-recent eruption of the Soufriere Hills volcano. The cruise successfully collected 23 multicores to the south-west of Montserrat. Many of these multicores successfully penetrated through the entire set of deposits from the 1995-recent eruption sequence, and contain the surge deposit. A series of ROV dives on a major flank collapse deposit offshore SE Montserrat provided the first detailed ROV footage of such collapse deposits, especially a collapse (Deposit 1) that occurred ~14 ka BP. A key result is that this collapse deposit contains many limestone blocks, presumably sourced from the carbonate platform around the island. This resolves a major question posed by IODP leg 340 in 2012. A series of gravity cores were also collected off Antigua. Although the cores failed to penetrate deeply, they help to constrain the age of a major collapse on that non volcanic island.

Key words: Montserrat, debris avalanche, volcano, submarine landslide, vibracorer

2. CONTENTS

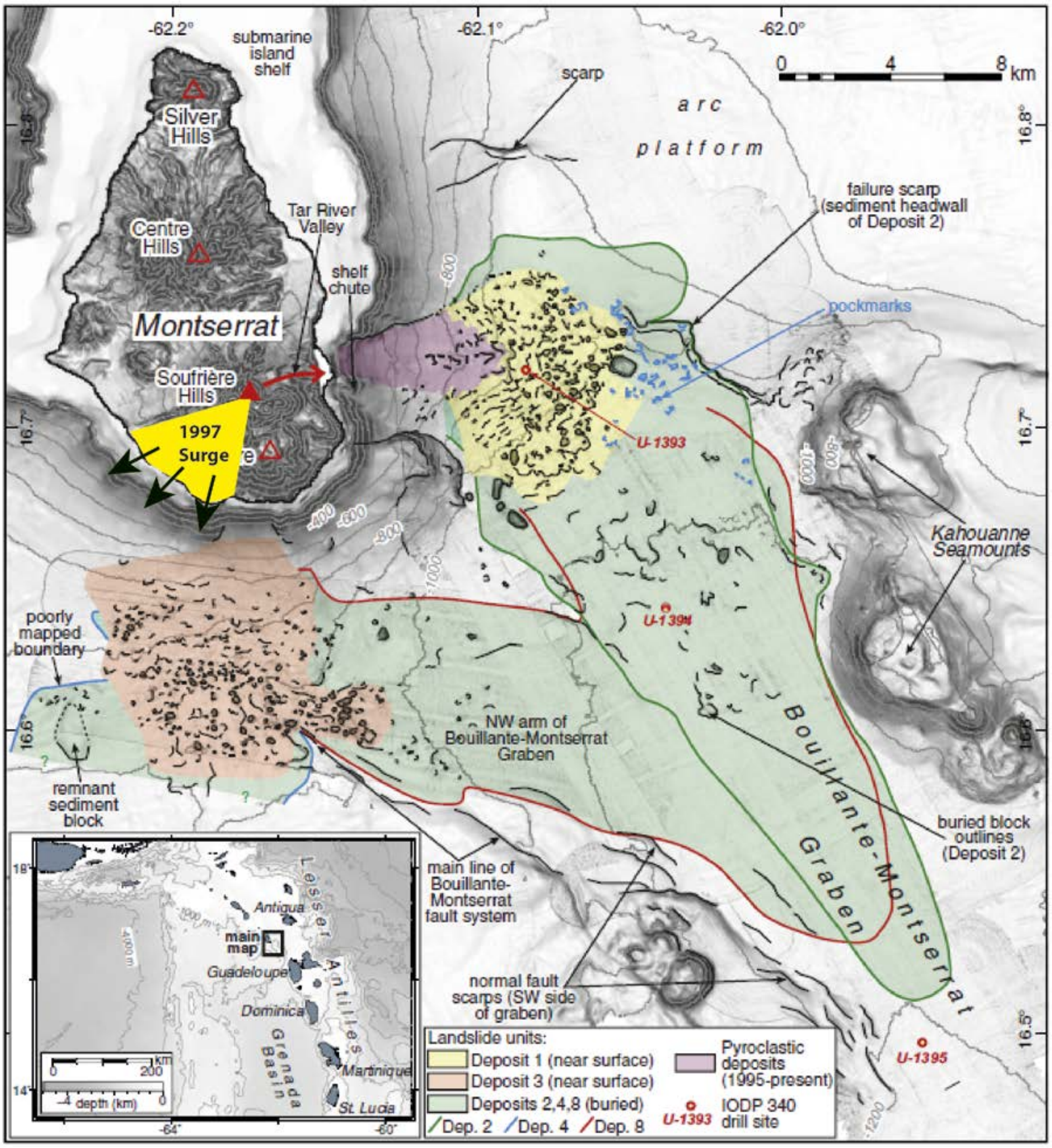

Figure 1. Location map of Montserrat (from Watt et al., 2013) showing location of major landslides (Deposits 1-8), IODP Expedition 340 drill cores (U1393-96), ridge of deposits from 1995-recent volcanic dome collapses (purple), and the sector of the island devastated by a pyroclastic surge in 1997 (yellow).

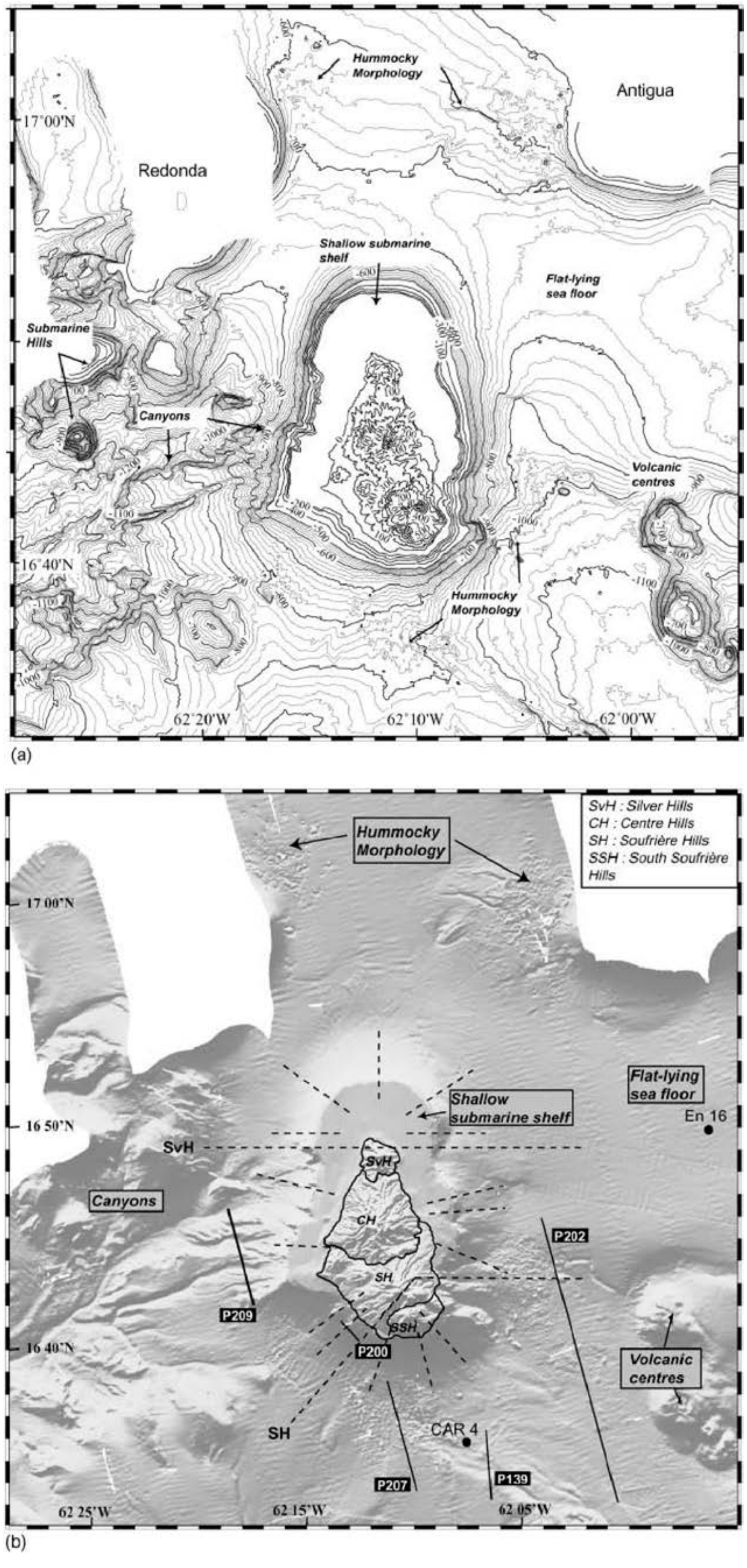

Figure 2. Location map showing Montserrat, and the large debris avalanche offshore from SE Antigua and Redonda (from Deplus et al., 2001).

3. PERSONNEL

SCIENTIFIC PERSONNEL

Pete Talling (PSO)	National Oceanography Centre, UK
Veit Hühnerbach	National Oceanography Centre, UK
Steve Roberts	University of Southampton
Alex Webber	University of Southampton
Matt Hodgkinson	University of Southampton
Rachel Mills	University of Southampton
Jeff Hawkes	University of Southampton
Alastair Lough	University of Southampton
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Alain Castillo	CNRS, Paris
Kate Stansfield	University of Southampton
Tim Le Bas	National Oceanography Centre, UK
Bramley Murton	National Oceanography Centre, UK
Leigh Marsh	University of Southampton
Adrian Glover	National History Museum, London
Paul Tyler	University of Southampton
Verity Nye	University of Southampton
Andy Thaler	USA
Will Homoky	University of Southampton

TECHNICAL PERSONNEL

Paul Provost	NMFD
James Cooper	NMFD
Alan Davies	NMFD
David Edge	NMFD
Mark Maltby	NMFD
William Handley	NMFD

Russell Locke	NMFD
David Turner	NMFD
Alan Sherring	NMFD
Andrew Webb	NMFD

SHIP'S PERSONNEL

Master	Peter Sargeant
C/O	James Gwinnell
2/O	Iain McCleod
C/E	Robert Lucas
3/O	Paul Munro
2/E	Mike Murray
3/E	David Jordan
3/E	Gary Slater

4. ITINERARY

Departed JC82 work area off Cayman Trough: 04:00 (local) on 25th February 2013.

Arrived JC83 work area off Montserrat: 10:00 (local) on 1st March 2013.

Arrived: St John's in Antigua 0800 (local) on March 8th.

5. BACKGROUND

Volcaniclastic sediment is dispersed into the ocean through processes that include some of the most hazardous and violent events on Earth, such as flank collapse landslides, pyroclastic flows and surges. Flank collapses generate the largest mass flows on our planet, which can produce damaging far field tsunamis. Even during relatively small eruptions of island arc volcanoes, most of the erupted mass is transported into the ocean. The marine record of eruptions is thus often more complete and easier to read than the subaerial record. Understanding how submarine deposits record volcanic events is important for reconstructing volcanic histories, testing models of eruption dynamics, and predicting future patterns of volcanic activity and hazard.

Montserrat in the Lesser Antilles provides a seminal dataset for studying these potentially very hazardous events associated with volcanic islands. This field dataset now includes arguably the most complete set of short (< 10 m long) marine cores located offshore from a volcanic island (Trofimovs, 2006, 2008, 2010, 2012, 2013; Cassidy, 2012), most detailed 2D and 3D seismic data (Watt et al., 2012a,b; Crutchley et al., 2012; Kastens et al., 2013), first repeat multibeam surveys (Le Friant et al., 2011; Trofimovs et al., 2012), first detailed ROV surveys in 2013, and the first IODP drilling of volcanic island landslides during Expedition 340 in 2012. This exceptional offshore dataset complements the unusually detailed observations made on land, including studies of the ongoing eruption of the Soufriere Hills volcano since 1995. The 1995-recent eruption sequence included a series of volcanic dome collapses that sent pyroclastic flows into the ocean (Trofimovs et al., 2006, 2008, 2011), which included the largest volume dome collapse yet recorded in historical times with a volume of 0.23 km^3. An even more violent pyroclastic surge occurred on Montserrat in 1997 that devastated a sector on the SE of the island (Sparks et al., 2002). Seismic data and IODP drill cores document a series of far larger collapse events with volumes of 1-20 km^3

(Le Bas et al., 2011; Watt et al., 2012a,b). The most recent large collapse produced a blocky deposit (Deposit 1), whilst an even larger and older failure (Deposit 2) was sampled within IODP Drill cores. An exciting initial result of the IODP drill cores was that flank-collapse Deposit 2 does appear to be associated with a major volcanic eruption with an unusual mafic composition.

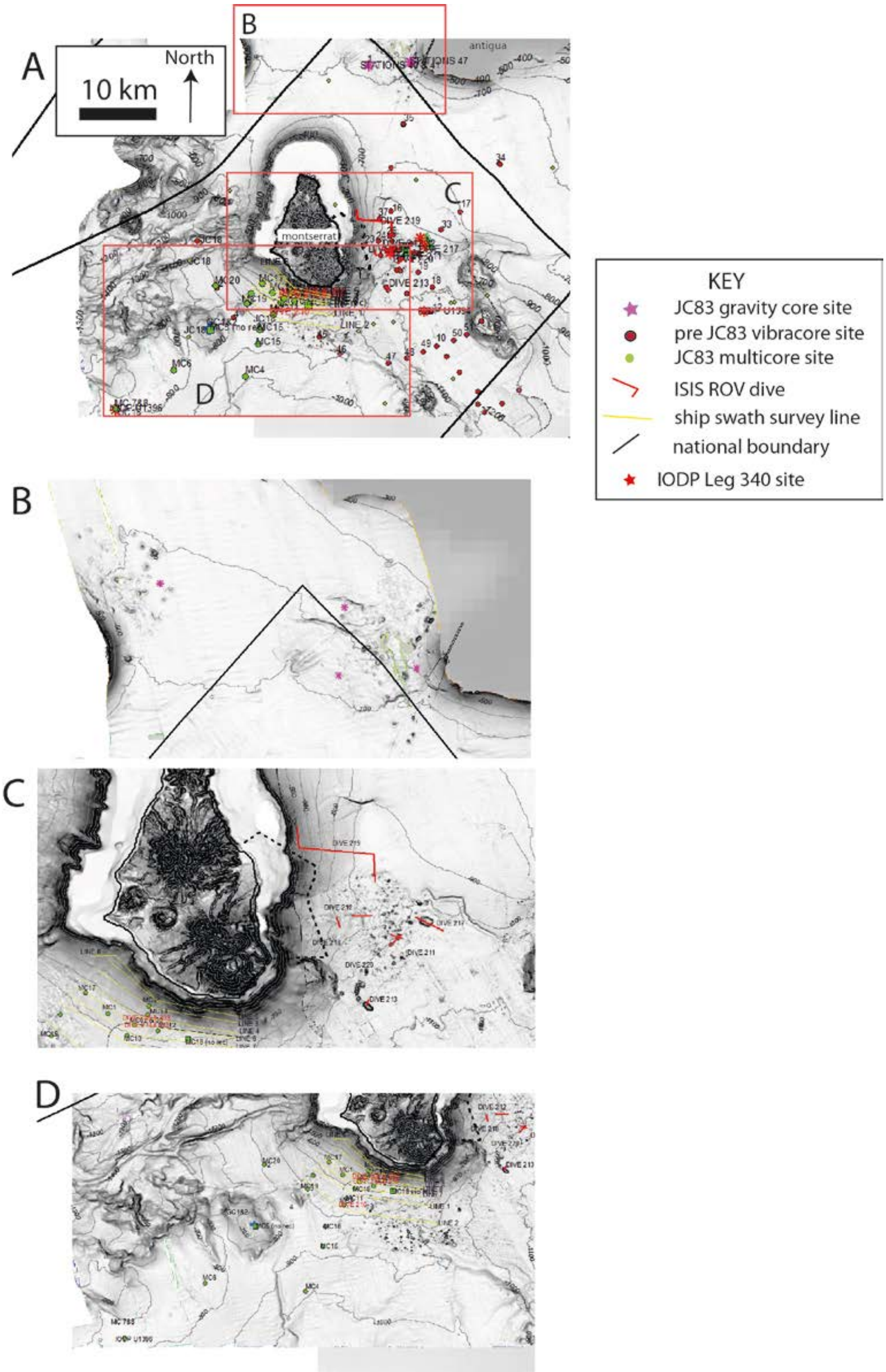

Figure 3. Location maps showing ISIS ROV Dives (208-219), ship-track for swath bathymetric survey (yellow lines), gravity cores off Antigua (stars), and multicores (green dots) collected during JC83. Also shown are previously collected vibracores during cruise JCR123, and IODP Expedition 340.

6. CRUISE OBJECTIVES

This short (7 day) cruise offshore Montserrat in the Lesser Antilles was funded by a (technology led) NERC standard grant.

The first aim of JC83 was to test a new ROV-mounted vibracorer on the UK ROV ISIS. This would be the first vibracorer available for science worldwide of its type. The vibracorer was able to obtain 80cm long cores, but further work is now needed to increase the strength of the vibrator motor.

There were also two main science aims. The first aim was to obtain a grid of samples from a pyroclastic surge deposit emplaced offshore SW Montserrat in 1997. This surge was remarkably destructive on land with speeds in excess of 80 m/s. Multicoring was very successful and these are the first detailed samples worldwide from this type of deposit. This will help us to recognise the offshore record (and frequency) of dangerous surge events in other locations worldwide. The second aim was to use the ROV ISIS to better understand the composition, source and emplacement dynamics of very large volcanic flank collapse events. This was also very successful, and determined the composition and origin of the last major collapse event at ~14 ka.

7. METHODS

ROV-dives: A series of dives were completed with the ISIS ROV in water depths of up to 900m (Fig. 1). The dives were intended to test the new ROV vibracorer. They were also able to collect video footage of the seafloor, in some locations including blocks within volcanic debris avalanches.

Unfortunately both manipulator arms of the ROV malfunctioned and it was therefore unable to collect physical samples. However, the high resolution video and still images allowed constrained to be placed on block composition. The RESON swath bathymetry system on ISIS also malfunctioned, such that bathymetric mapping could not be undertaken. However, ship-mounted EM710 swath bathymetry was collected.

Multi-cores: A series of 23 multicores were collected, and the system consistently produced good recovery of sediment cores off SE Montserrat that are up to ~60cm in length. Due to a lack of spare tubes – typically only the best core barrel was archived at each individual station.

Gravity cores: Four gravity cores were collected offshore SE Antigua.

EM710 Swath Multibeam and Sub-bottom Profiler data was collected offshore SE Montserrat and Antigua.

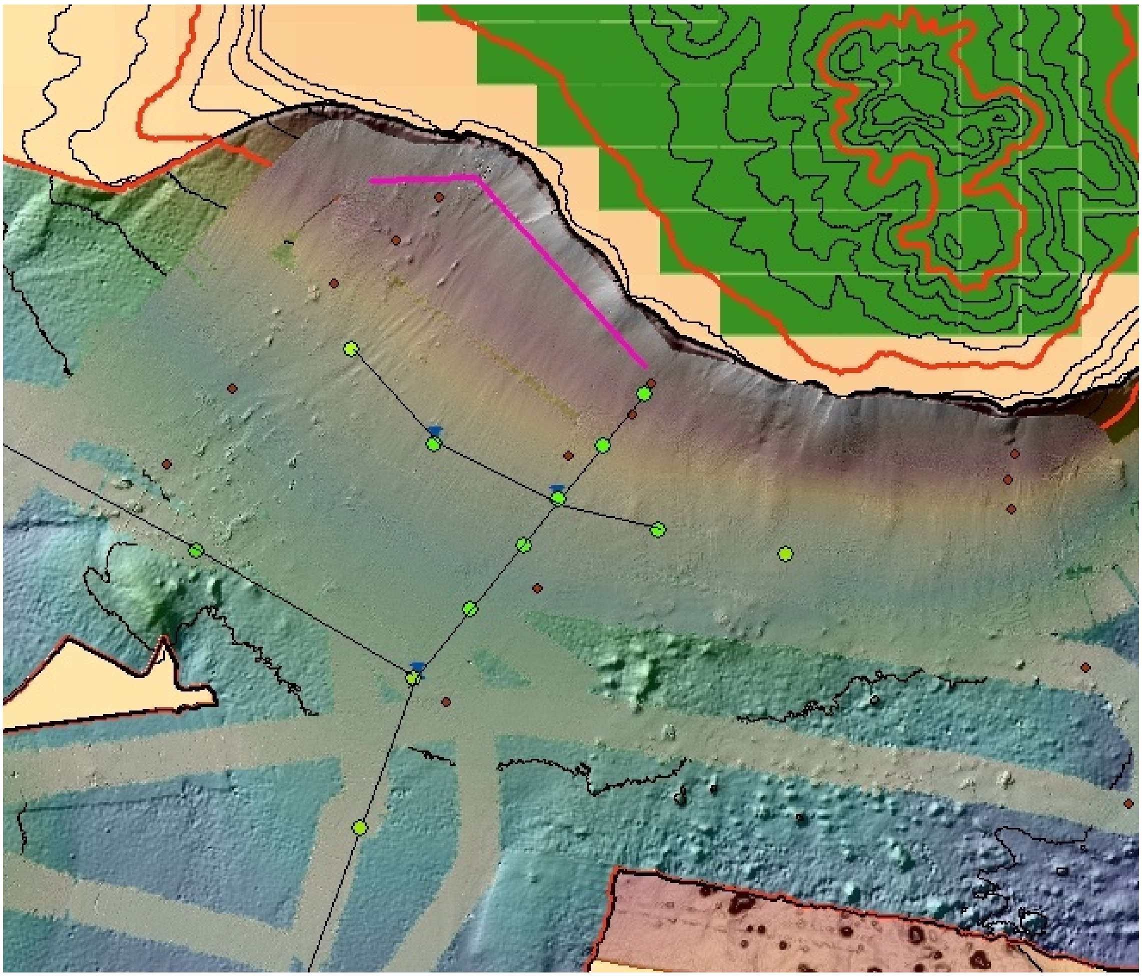

Figure 4. EM710 swath multibeam map collected during JC83, superimposed on older and coarser bathymetric data. The green dots are multicores, and red diamonds are the termination of lines in swath survey. Purple line is final swath line. Note the recent landslide offshore Plymouth, in top left of picture.

8. OPERATION OF NEW ROV-VIBRACORER

The Vibrocorer is powered from its own power pack consisting of two pumps and a valve pack. These pumps are supplied from the Isis hydraulic unit. The Slurp function on the Isis manifold drives pump B. (Clamp, Winch, Cut). The Rotate function drives pump A. (Vibrator). Hydro Lek systems filled with Morlena 10.

Figure 5. ISIS with vibracorer attached.

Isis Hydraulics and set up:

Motor speed: 1500rpm
Pressure: 1500psi (Both pumps running for max flow)
Manifold set to 70%
Rotate function set to 75%
Slurp function set to 75%
(Do not ramp up vibrator from a low setting on flow control valve as this has a tendency for making the vibrator get stuck) If this happens, a tap with a rubber mallet seemed to do the trick.

Vibrator:
Max pressure 800-1000psi

4 GPM gives 10,800 Vibrations Per Min (18L/min)
3 GPM gives 8,100 VPM (13.5L/min)

Dive 208 (16° 40.004 62° 15.700; 660 m)

Aborted due to chopped comp line to removed science P&T

Dive 209 (16° 39.632 62° 13.679; 646 m)

Buoyancy and trim check on surface.
Buoyancy at depth approx +ve 40kg

Approx. 122kg of down thrust applied by ROV whilst taking core.
Core barely went in.

All Hyd systems working well. The sediment was not known to be core-able, and there appeared to be lots of rock and debris in the vicinity. The decision to move to a known site that had been vibro-cored before by BGS was chosen for the next dive. This was approx 3km away.

Changes to be made for 210:

- Mark white lines on winch cheek plates
- 10cm marks on core tubes
- Add lead

Dive 210 (16° 38.076 62° 14.747; 763 m)

Approx 15kg of lead added to this dive

Isis thruster down force 118kg. Depth Bias 40kg.

The core tube was lifted above the cutter, the cutter was closed and the core lowered on top to help seal core for ascent and recovery.

0.45m penetration achieved. The core was washed out on surface.

Changes to be made for dive 211:

- Add more lead

Dive 211 (16° 42.693 62° 16.04.072; 943 m)

Total lead added now approx. 30-35kg
Isis thruster down force 118kg
Depth Bias 20kg
Core catcher has had tights removed and a plastic bag used instead.
No improvement on core penetration.

Changes/tests for dive 212:

- The spare Vibrator was connected to the Hydro Lek pump to see if it had a better performance. This unit made no difference.
- The Hydro Lek pump A was checked for flow output.
  5-6L/min was recorded with the Isis motor running at 1500rpm with both pumps running (<1500psi)

Note: this flow rate is well below the min required for optimum vibration. The correct flow required by the vibrator is between 13.5 and 18L/min.

Dive 212 (16° 43.101° 62 05.854; 919 m)

15kg weight on Vibrator
Isis thruster down force 118kg
Depth Bias 40kg
400mm penetration

Dive 213 (16° 40.175° 62 05.278; 958 m)

35kg weight on vibrator
Isis thruster down force 118kg
Depth Bias 20kg
A 450mm core was achieved, of which the majority was taken with the weight of the winch and lead, due to soft sediment.

Changes/tests for dive 214:

Due to low the low flow from Hydro Lek pump some flow measurements were taken from Isis Port manip manifold. These ports come directly off the Isis valve pack and not through the Isis manifold, and therefore supply a higher flow rate.
The thinking behind this was that if the flow rate was higher than that of pump A on the Hydro Lek unit, it may be worth connecting direct to the Vibrator to see if the performance increased.
At 1500rpm, 1000psi (max allowed into vibrator) the flow produced was 15.5L/min.

To avoid any contamination on the Isis hydraulic system and to flush through the different oil used, the Vibrator was connected to the port manipulator hydraulic supply line, with the return line rtn going into a bucket. The unit was then run flushing the oil through the vibrator and into the bucket. The return line was then connected back to tank and the vibrator run. This increased oil flow considerably improved the vibrations produced.
This configuration was then used for the following two dives, in the same place but with different weight amounts.

Dive 214 (16°39.735 62°13.939; 640 m)

15kg weight on Vibrocorer
Isis thruster down force 118kg
Depth Bias 40kg
The location chosen to be less muddy and more suitable for vibrator
An 18cm penetration achieved
The sediment was found to be of a fine consistency.

Dive 215 (16°39.494 62°16.933; 645 m)

35kg of weight on Vibrocorer
Isis thruster down force 118kg
Depth Bias 20kg
Same location as dive 214
The penetration was the same as before, with the weight making no difference.

Dive 215 was the last of the Vibrocore trials on JC083

Conclusion:

- The engineering of the Vibrocorer worked very well. The slide arm and winch system were reliable.
- The performance of Pump A needs to be investigated further. The suction pump valve on the Isis manifold may not be producing the required flow for Pump A. This could possibly be rectified by connecting to the stbd manipulator flow and rtn lines. See comments on last two dives.
- The performance of the Vibrator needs to be compared with the MBARI system. The vibrator motor appears to be underpowered for penetration.
- Up to 40kg of lead weight was added to the vibracorer slide arm, but this has little affect on penetration.
- The vibracorer is not intended to penetrate sequences cohesive clay, but it penetrated up to 45 cm in one location on a mega-block (thereby helping to constrain the emplacement age).
- The character of the sand (sorting etc) could have a significant effect on vibracorer penetration based on past experience.

9. NARRATIVE (times in GMT except where otherwise stated)

Monday 25.Feb.2013:

8.00 GMT (04.00 local) finish science for JC82 in Cayman Trough.

Transit - Setting up equipment, life boat drill etc:

Made good time.

Quiver of extra cores removed to aid vision; only one core per site planned. But trial on deck shows tube can be placed in system from quiver.

Friday 1.March.2013:

12.30 GMT (8.30 local) arrived Work Area 1 – offshore SW Montserrat. Very calm conditions.

Put piston coring cradle on side of ship.

12.43 GMT Waypoint 1 (16° 40.891 62° 16.0001; 640 m) Started ship 210/710 swath: 710 initially not working until first core site

13.22 GMT Start of turn (16° 39.451 62° 13.433; 658 m) EM 710 not working on this line

13.44 GMT Waypoint 2 (16° 37.960 62° 14.627; 644 m)

14.22 GMT Arrive STATION 1: MEGACORE 1 (WITH SVP): (16° 39.950 62° 14.513; 641 m)

14.36 GMT Deployed Megacorer 1 (with SVP) (16° 39.950 62° 14.513; 641 m)

15.03 GMT Megacorer on seabed (16° 39.952 62° 14.593; 660 m). Pullout = 1.25 tonnes

15.29 GMT Megacorer on deck (16° 39.952 62° 14.592; 643 m)

1 successful tube; with ~25cm dark volcanic sand

16.10 GMT STATION 2: ROV ISIS DIVE 208 (16° 40.004 62° 15.700; 660 m)

DIVE ABORTED AS HYRUALIC HOSE LEAKING

17.43 GMT **STATION 3: MEGACORE 2 (**16° 39.512 62° 13.605; 658 m) deployed

18.03 GMT Megacorer on seabed (16° 39.509 62° 13.577; 641 m). Pullout = 2.23 t

18.25 GMT Megacorer on deck (16° 39.509 62° 13.577; 640 m).

Good recovery – 2 tubes of volcanic sand

1900 GMT **STATION 4: ISIS ROV DIVE 209 (16° 39.632 62° 13.679; 646 m)**

No penetration

Video observations: Isolated m-scale boulders or boulder clusters every few 10's m, surrounded by flatter areas coarse sand. Some winnowing and moats around boulders. Wood (some large branches).

Biology samples recovered

2353 GMT **STATION 5: ISIS ROV DIVE 210 (16° 38.076 62° 14.747; 763 m)**

Added 20 kg in lead weights to slide arm

Penetration to 45cm; but sand fell out during recovery

Flat rippled areas of finer sand that 209. Only one rock seen, and rarer wood.

Biology samples recovered

Saturday 2nd March

0049 GMT **STATION 6: Megacore 3 (16° 38.182 62° 14.747; 763 m) at 'Site 3'**

Same location as end of Dive 209.

0322 GMT On seabed; Pullout 1.82 t;

0358 GMT Core on deck: 1 good tube – 55 cm long.

0453 GMT **STATION 7: Megacore 4 (16° 33.224 62° 16.688; 982 m) at 'Site 4'**

0523 GMT On seabed; Pullout 1.95 t;

0622 GMT Core on deck: 2 good tubes – 70 cm long.

0705GMT **STATION 8: Megacore 5 (16° 36.974 62° 19.626; 611 m) at 'Site 5'**

On top of large hill: Pullout 1.40 t;

0758 GMT Core on deck (16° 37.043 62° 19.623; 588 m) at 'Site 5'

No cores recovered; just two residual bags

0847 GMT **STATION 9 Megacore 6 (16° 33.690 62° 22.500; 733 m) at 'Site 6'**

0912 GMT Megacore on seabed. (16° 33.690 62° 22.500; 733 m) Pull out 1.89 t.

0956 GMT core on deck (16° 33.691 62° 22.504; 743 m)

2 good tubes recovered and 1 small residual bag.

1048 GMT STATION 10 Megacore 7 (16° 30.488 62° 27.097; 733 m) at 'Site 7' (IODP U1396)

1114 GMT core on seabed (16° 30.490 62° 27.095; 787 m) pullout 2.24 t.

Nice SBP data

1152 GMT core on deck (16° 30.490 62° 27.095; 733 m)

Cores overflowed with sediment – *so buried below sed-water interface*

One full core tube recovered

1208 GMT STATION 11 Megacore 8 (16° 30.490 62° 27.100; 787 m) at 'Site 7' (IODP U1396)

Redeployment of megacorer at IODP Site U1396 with 4 core tubes (all megacores were previously deployed with 2 tubes

1236 GMT Core on seabed. (16° 30.491 62° 27.100; 787 m) Pullout 2.25 t.

1311 GMT Core on deck (16° 30.490 62° 27.095; 786 m). 4 good tubes recovered with sediment-water interface preserved

1503 GMT STATION 12: Ship multibeam survey starts: (16° 40.33 62° 16.28; 730 m).

Start of line 1

1623 GMT Waypoints (see waypoints list) 889m. End of line 1 (W>>E)

1636 GMT Start of Line 2 916 m (E>>W)

18.06 GMT End of Line 2. 789m

1847 GMT Start of Line 5 (W>>E). order changed to do inner line during daylight

1956 GMT End of Line 5. 451m

2011 GMT Start of Line 4. 564 m (E>>W)

2126 GMT Endof Line 4.

2136 GMT Start of Line 3 (W>>E)

2257 GMT End of Line 3

Ship EM120/710 waypoint	*Latitude*	*Longitude*	*Approx depth*
Line1	**16 40.335384**	**62 16.286011**	**780**
Line 1	**16 38.750663**	**62 13.763307**	**830**
Line 1	**16 38.125341**	**62 09.2283258**	**830**
Line2	**16 37.052649**	**62 08.865265**	**900**

Line 2	**16 37.852148**	**62 14.51884**	**780**
Line 2	**16 39.736681**	**62 16.825989**	**780**
Line 5 start	**16 41.85586**	**62 14.572799**	**400**
Line 5 mid	**16 40.382497**	**62 12.82104**	**400**
Line 5 finish	**16 39.825704**	**62 09.801504**	**400 (but shallows to 200 m along line**
Line 4	**16 39.615835**	**62 09.861467**	**530**
Line 4	**16 40.142648**	**62 12.975229**	**530**
Line 4	**16 41.521783**	**62 14.924008**	**510**
Line 3	**16 41.170575**	**62 15.433688**	**610**
Line 3	**16 39.812854**	**62 13.506325**	**610**
Line 3	**16 39.176**	**62 09.826**	**610**

Lines numbers from further from island (1) to nearest to island (5)

Sunday 3rd March

0040 GMT **STATION 13: ISIS ROV DIVE 211: (16° 42.693 62° 16.04.072; 943 m)**

"ROV CORE SITE 7" in work area 2 – where BGS vibracore 54 comes from

TRIAL OF VIBRACORER (also see DIVE LOG SHEET)

0040 GMT ISIS in water:

0338 GMT ISIS on seafloor

Arrived on top of block (959m). 10cm scale blocks and surrounding sand dappled floor. Heading uphill, v. angular blocks of dome rock. Went down hill to flat area between blocks where BGS vibracore 54 located.

Vibracorer deployed. 10cm penetration mainly under own weight not vibrations, with 110kg (not adjusted for water) ROV downthrust.

0503 GMT **Testing hydraulic flow rate on deck**

NB On deck found that flow rate was 5 l/min, whereas should be 15-18 l/min – so this and previous dives have very weak vibrations.

0555 GMT **STATION 14: ISIS ROV DIVE 212: (16° 43.101° 62 05.854; 919 m).**

"ROV CORE SITE 8" in work area 2 – on pyroclastic flow ridge – very sandy

TRIAL OF VIBRACORER (also see DIVE LOG SHEET)

Slide arm has +35kg weight (damps vibrations?) < 20cm penetration mainly under own weight.

0555 GMT ISIS deployed (16° 43.101° 62 05.854; 919 m).

0648 GMT ISIS on seafloor **(**16° 43.463° 62 05.047; 914 m).

0725 GMT Vibracore attempt ISIS on seafloor **(**16° 43.450° 62 05.185; 915 m).

18 cm penetration, but sand later flowed out of core catcher.

0930 GMT ISIS on deck **(**16° 43.473° 62 05.423; ~866 m).

1028 GMT STATION 15: ISIS ROV DIVE 213: (16° 40.175° 62 05.278; 958 m).

"ROV CORE SITE 9" in work area 2 – on southern mega-block

TRIAL OF VIBRACORER (also see DIVE LOG SHEET)

1034 GMT ISIS deployed (16° 40.175° 62 05.278; 958 m).

1133 GMT ISIS on seafloor **(**16° 40.199° 62 05.277; 965 m).

1225 GMT Vibracore attempt ISIS on seafloor **(**16° 40.172° 62 05.234; 967 m).

Penetration of 80cm, but by weight not by vibrations. No further penetration while vibrating. (35kg weight on slider?)

1243 GMT end coring, transiting E downslope

1353 GMT leaving seafloor **(**16° 40.153° 62 05.214; ~962 m).

1506 GMT ISIS on deck **(**16° 40.152° 62 05.235; ~962 m).

1615 GMT STATION 16: SHIP MULTIBEAM ES SURVEY

1615 GMT Start Line6 (E>>W) (16° 39.080 62° 09.872; ~? m).NB "line 1 on log sheets"

1732 GMT End of Line 6 (653m) (16° 40.904 62° 15.712; 694 m).

Waypoint 1	**16° 39.080**	**62° 09.872**
Waypoint 2	**16° 39.538**	**62° 13.573**
Waypoint 3	**16° 40.904**	**62° 15.712**

1748 GMT Start Line7 (W>>E) (16° 40.597 62° 15.976; 694 m).NB "line 2 on log sheets"

? ??? GMT End of Line 7 (653m) (16° 38.68462° 09.950; ? m).

Waypoint 4	**16° 40.597**	**62° 15.976**
Waypoint 5	**16° 39.155**	**62° 13.665**
Waypoint 6	**16° 38.684**	**62° 09.950**

2018 GMT STATION 17: ISIS ROV DIVE 214: (16°39.735 62°13.939; 640 m).

"REOCCUPATION OF ROV CORE SITE 2" in work area 1: with stronger flow rate and vibrations. 15kg extra weight on slide arm (two circular lead weights)

TRIAL OF VIBRACORER (also see DIVE LOG SHEET)

2018 GMT ISIS deployed (16°39.735 62°13.939; 640 m).

2055 GMT ISIS on seafloor **(**16° 39.547° 62° 13.575 ; 639 m).

Less common blocks seen that on previous occupation of this site.

2102 GMT Vibracore attempt ISIS on seafloor **(**16° 39.515° 62° 13.556; 652 m).

92 kg ROV downthrust; only 5cm penetration initially; but vibrations clearer on video. VERY slow penetration to 16 cm, at ~3cm in 15 minutes, then 1 cm in 10 minutes.

2224GMT ISIS on deck **(**16° 39.492° 62° 14.031; ~640 m).

Tested on deck on wood block. 35kg slider weight seems to reduce strength of vibrations to about 70% of 15kg slider weight – by qualitative holding of barrel.

2018 GMT STATION 18: ISIS ROV DIVE 215: (16°39.494 62°16.933; 645 m).

SAME SITE AS DIVE 214 BUT WITH 35kg ON SLIDE ARM

"REOCCUPATION OF ROV CORE SITE 2" in work area 1: with stronger flow rate and vibrations. 35kg extra weight on slide arm (two circular lead weights)

TRIAL OF VIBRACORER (also see DIVE LOG SHEET)

No more penetration than last dive. 18cm in total – VERY slow.

2354 GMT ISIS on deck **(**16° 39.486° 62° 13.560; ~640 m).

Monday 4th March

0040 GMT STATION 19: Megacore 9 (16° 39.466 62° 13.602; 663 m)

Same "ROV core site 2" location as ISIS DIVES 214/15

0109 GMT Megacore on seabed. (16° 39.466 62° 13.602; 663 m) Pull out 1.89 t.

0137 GMT core on deck (16° 33.691 62° 22.504; 663 m)

2 good tubes recovered – 1 kept?

0209 GMT STATION 20: Megacore 10 (16° 39.106 62° 13.871; 703 m)

0238 GMT Megacore on seabed. (16° 39.106 62° 13.871; 703 m) Pull out 1.44 t.

0303 GMT core on deck

0322 GMT STATION 21: Megacore 11 (16° 38.587 62° 14.303; 745 m)

0351 GMT Megacore on seabed. (16° 38.587 62° 14.304; 745 m) Pull out 1.71 t.

0421 GMT core on deck

0504 GMT STATION 22: Megacore 12 (16° 39.227 62° 12.742; 664 m)

0529 GMT Megacore on seabed. (16° 39.227 62° 12.742; 664 m) Pull out 1.43 t.

0554 GMT core on deck (2 reasonable tubes – one has air void so discarded)

0625 GMT STATION 23: Megacore 13 (16° 39.882 62° 13.219; 592 m)

0645 GMT Megacore on seabed. (16° 39.882 62° 13.219; 592 m) Pull out 1.36 t.

0708 GMT core on deck (2 short tubes – one discarded)

0738 GMT STATION 24: Megacore 14 (16° 40.164 62° 13.047 528 m)

0757 GMT Megacore on seabed. (16° 40.164 62° 13.047 528 m) Pull out 1.24 t.

0822 GMT core on deck (2 short tubes – one kept?)

****** GMT STATION 25: ISIS ROV DIVE 216: (RESON SURVEY – UP SURGE FLOW PATH)**

DIVE ABORTED AND ROV ON DECK

1153 GMT STATION 26: 710 kHz Swath Survey – filling in gap.

1153 GMT	**Start line 8 ("1 in log")**	**16° 38.558**	**62° 14.885 (756m) (E>W)**
1225 GMT	**End Line 8 ("1 in log")**	**16° 40.519**	**62° 17.137 (763m) (E>W)**
1237 GMT	**Start Line 9 ("2 in log")**	**16° 40.481**	**62° 17.058 (762m) (W>E)**
1318 GMT	**End Line 98 ("2 in log")**	**16° 38.462**	**62° 14.136(752m) (W>E)**

1439 GMT STATION 27: GRAVITY CORE 01 (16° 37.057 62° 19.622; 604 m)

(at ROV Core site 5 on hill top); 3 m barrel.

1502 GMT Megacore on seabed. (16° 37.058 62° 19.619; 604 m) Pull out 2.10 t. (fell over?)

1533 GMT core on deck (16° 37.058 62° 19.619; 604 m)

No recovery (empty)

1439 GMT STATION 28: GRAVITY CORE 02 (16° 37.057 62° 19.622; 604 m)

(at ROV Core site 5 on hill top); 3 m barrel; same as station 27.

1502 GMT Megacore on seabed. (16° 37.058 62° 19.619; 604 m) Pull out 2.09 t. (fell over?)

1533 GMT core on deck (16° 37.067 62° 19.637; 604 m)

No recovery (empty)

1718 GMT STATION 29: Megacore 15 (16° 35.799 62° 15.678 872 m)

1744 GMT Megacore on seabed. (16° 35.799 62° 15.678 872 m) Pull out 1.77 t.

1816 GMT core on deck (2 short tubes – only one kept)

1841 GMT STATION 30: Megacore 16 (16° 36.887 62° 15.256 828m)

1903 GMT Megacore on seabed. (16° 36.887 62° 15.254 828m) Pull out 1.65 t.

1930 GMT core on deck (2 short tubes – only one kept)

2009 GMT STATION 31: Megacore 17 (16° 40.688 62° 15.322 652m)

2030 GMT Megacore on seabed. (16° 40.688 62° 15.322 652m) Pull out 1.35 t.

2053 GMT core on deck (one of 2)

2125 GMT STATION 32: 710 kHz Swath Survey – filling in gap – close to Plymouth shoreline

Waypoint 1	**16 ° 41.986**	**62 ° 15.125**
Waypoint 2	**16 ° 42.020**	**62 ° 14.255**
Waypoint 3	**16 ° 40.298**	**62 ° 12.679**

2216 GMT STATION 33: Megacore 18 (16° 39.039 62° 11.700 685m)

GMT Megacore on seabed. Pull out 1.37 t.

2304 GMT no recovery (empty) – one tube did not fire – irregular seafloor

2341 GMT STATION 34: Megacore 19 (16° 39.097 62° 16.537 758m)

Same location as JCR123 BGS vibracore 3

Tuesday 5th March

0005 GMT Megacore on seabed. Pull out 1.66 t.

NB – Sub bottom profiler interesting here

0028GMT core on deck (2 of 2) – only 1 archived

0100 GMT STATION 35: Megacore 20 (16° 40.352 62° 19.012 878 m)

0122 GMT Megacore on seabed. Pull out 1.82 t.

0148 GMT 2 of 2 – both preserved – 60 cm long

Work Area 2

0437 GMT STATION 36: ISIS ROV DIVE 217: (16°42.189 62°04.863; 1023 m).

LARGEST ("WEMBLEY") MEGA-BLOCK IN WORK AREA 2

NO RESON OR VIBRACORER; JUST CAMERAS; INCLUDING SCORPIO SYSTEM ADDED

SEE DIVE LOG SHEET

0437 GMT ISIS deployed (16°42.189 62°04.863; 1023 m).

0535 GMT ISIS on seafloor **(**16° 42.894° 62° 02.494 ; 1029 m).

0539 GMT Start of transect line. Flat, rippled sand. Seagrass, no large blocks – even on radar

WAYPOINT 1; In pockmark. LIMESTONE (!) with shells embedded in rock on video in NW face of pock mark. Limestone nicely bedded.

Beyond pockmark, seafloor is flat and sandy.

10.41 GMT ISIS off seafloor **(**16° 43.511° 62° 03.514; ~966 m). from top of last mound

ISIS Recovered

1432 GMT STATION 37: ISIS ROV DIVE 218: (16°43.226 62°06.228; 791 m).

SHORT TRANSECT ACROSS PYROCLASTIC FLOW RIDGE IN WORK AREA 2

NO RESON OR VIBRACORER; JUST CAMERAS; INCLUDING SCORPIO SYSTEM ADDED

SEE DIVE LOG SHEET

1432 GMT ISIS deployed (16°43.226 62°06.228; 791 m).

1517 GMT ISIS on seafloor (16°43.213 62°06.339 772 m).

1605 GMT ISIS off bottom **(**16° 43.361° 62° 06.332 ; 787 m).

1648 GMT ISIS on deck **(**16° 43.361° 62° 06.332 ; 785 m).

1736 GMT STATION 38: ISIS ROV DIVE 219: (16°44.669 62°04.892; 934 m).

LONG TRANSECT STARTING ON DEPOSIT 1 MOUNDS; THEN ALL WAY UP 2010 PYROCLASTIC FLOW TRACK ON TOBI; THEN SMALL LEG NORTH

NO RESON OR VIBRACORER; JUST CAMERAS; INCLUDING SCORPIO SYSTEM ADDED

SEE DIVE LOG SHEET

1736 GMT ISIS deployed (16°44.669 62°04.892; 934 m).

1826 GMT ISIS on seafloor (16°44.660 62°04.998 928 m).

Wednesday 6th March

0556 GMT End of central, longest line **(**16° 45.877° 62° 07.686 ; 432 m).

0638 GMT ISIS off bottom **(**16° 45.000° 62° 07.665 ; 455 m).

0708 GMT ISIS on deck **(**16° 45.989° 62° 07.620 ; 455 m).

0829 GMT STATION 39 ISIS ROV DIVE 220: (16°42.357 62°04.438; 975 m).

EXTRA DIVES ON DEPOSIT 1 BLOCKS ENDING NEAR OLD 'ROV CORE SITE 7'

NO RESON OR VIBRACORER; JUST CAMERAS; INCLUDING SCORPIO SYSTEM ADDED

SEE DIVE LOG SHEET

1826 GMT ISIS deployed (16°42.357 62°04.438; 975 m).

0925 GMT ISIS on seafloor (16°42.324 62°04.399; 994 m).

10.28 GMT	Bathynoma Gigantia swimming seen at 1028

1312 GMT	ISIS off seafloor **(**16° 42.841° 62° 04.067 ; 998 m).

1409 GMT	ISIS on deck **(**16° 42.827° 62° 04.130 ; 455 m).

Coring as ISIS ROV has to be on deck – stowed by 14.30 GMT

Work Area 3

**1921 GMT	STATION 40: Gravity Core 3 (16° 58.158 62° 06.817 662 m); 3m barrel**

ANTIGUA LANDSLIDE ('CORE SITE 1 IN GIS)

1940 GMT	Gravity core on seabed. (16° 58.158 62° 06.816 662 m);

Pull out 2.24 t. Note looks hard on SBP. Into seafloor at 40m/min

2000 GMT	Core on deck (16° 58.158 62° 06.817 662 m);

20cm of coarse bioclastic sand with muddy matrix in core catcher (bagged)

JC83/GC3-CC

**2042 GMT	STATION 41: Gravity Core 4 (16° 58.158 62° 06.817 662 m); 3m barrel**

ANTIGUA LANDSLIDE ('CORE SITE 1 IN GIS) – REPEAT DEPLOYMENT

2059 GMT	Gravity core on seabed. (16° 58.159 62° 06.817 662 m);

Pull out 2.29 t.

2119 GMT	Core on deck (16° 58.158 62° 06.817 662 m);

Core name: JC83_GC_04

**2240 GMT	STATION 42: Gravity Core 5 (17° 02.207 62° 14.531 619 m); 3m barrel**

REDONDA landslide (Core Site 2 in GIS) – looks well bedded on SBP

2255 GMT	Gravity core on seabed. (17° 02.270 62° 14.531 619 m);

Pull out 2.31 t.

2315 GMT	Core on deck (16° 58.158 62° 06.817 662 m);

Core name: JC83_GC_05 – 39 cm plus core catcher

**2340 GMT	STATION 43: Gravity Core 6 (17° 02.270 62° 14.531 619 m); 3m barrel**

REDONDA landslide – REPEATED DEPLOYMENT AT SAME SITE

2255 GMT	Gravity core on seabed. (17° 02.270 62° 14.531 619 m);

Pull out 2.29 t.

2315 GMT	Core on deck (17° 02.270 62° 14.531 619 m);

Core name: JC83_GC_05 – 36 cm plus 12 cm in core catcher

Thursday 7th March

0129 GMT STATION 44: Ship Swath Survey: collapse off Antigua (16° 58.983 62° 09.738 668 m); starting at 5 knts; speeded up to 6.5 knts.

	ANTIGUA AREA Ship swath	**lat**	**long**	depth
0129 GMT	**Line 1 start (S>N)**	**16° 58.983**	**62° 09.738**	668
	Line 1 finish (S>N)	**17° 02.441**	**62° 07.652**	
	Line 2 start (N>S)	**17° 02.51**	**62° 06.541**	
0340 GMT	**Line 2 finish (N>S)**	**16° 57.521**	**62° 09.541**	704
0355 GMT	**Line 3 start (S>N)**	**16° 56.988**	**62° 08.772**	707
0505 GMT	**Line 3 finish (S>N)**	**17° 03.659**	**62° 04.941**	486
0518 GMT	**Line 4 start (N>S)**	**17° 03.892**	**62° 03.848**	473
	Line 4 finish (N>S)	**16° 56.34**	**62° 07.796**	
0644 GMT	**Line 5 start (S>N)**	**16° 55.908**	**62° 06.766**	732
	Line 5 finish (S>N)	**17° 03.663**	**62° 03.044**	
	Line 6 start (N>S)	**17° 03.305**	**62° 02.493**	
	Line 6 finish (N>S)	**16° 55.588**	**62° 05.754**	
	Line 7 start (S>N)	**16° 55.346**	**62° 04.571**	
	Line 7 finish (S>N)	**17° 01.808**	**62° 02.296**	**477 m**
	Line 8 (shallow)	**17° 02.575**	**62° 01.280**	**440 m**
	Line 8 (shallow)	**17 º 03.427**	**62º 01.102**	**363 m**
1116 GMT	**Line 8 (shallow)**	**17 º 04.092**	**62º 02.528**	**403 m**

1203 GMT STATION 45: Gravity Core 7 (17° 01.146 62° 06.530 560 m); 3m barrel

ANTIGUA landslide – 'site 05' on western side on hard reflector mound

1219 GMT Gravity core on seabed. (17° 01.146 62° 06.528 561 m);

Pull out 2.26 t. ; @45 m/min

1235 GMT Core on deck (17° 01.145 62° 06.528 561 m);

Sediment washed out whilst coming up

1253 GMT STATION 46: Gravity Core 8 (17° 01.145 62° 06.530 561 m); 3m barrel

ANTIGUA landslide – 'site 05' on western side on hard reflector mound

Second core at same site

1307 GMT Gravity core on seabed. (17° 01.146 62° 06.528 561 m);

Pull out 2.20 t. ; @70 m/min

1323 GMT Core on deck (17° 01.147 62° 06.530 561 m);

Sediment washed out whilst coming up – no recovery

1411 GMT STATION 47: Gravity Core 9 (16° 58.535 62° 03.403 581 m); 3m barrel

ANTIGUA landslide – 'site 04' on east side on hard reflector mound

1426 GMT Gravity core on seabed. (16° 58.524 62° 03.400 580 m)

Pull out 2.03 t. ; @60 m/min

1442 GMT Core on deck (16° 58.523 62° 03.400 581 m)

Virtually no recovery – except mini plastic bag.

1646 GMT STATION 48: Gravity Core 10 (17° 09.029 62° 13.865 557 m); 3m barrel

Far north site on open seafloor ('site 03')

1700 GMT Gravity core on seabed. (17° 09.201 62° 13.874 556 m)

Pull out 3.13t. ; @50 m/min

1722 GMT Core on deck (17° 09.043 62° 13.884 556 m)

Virtually no recovery

1744 GMT STATION 49: Gravity Core 11 (17° 08.984 62° 13.880 558 m); 3m barrel

Far north site on open seafloor – repeated deployment ('site 03')

1800 GMT Gravity core on seabed. (17° 08.983 62° 13.880 558 m)

Pull out 2.19t. ; @35 m/min

1816 GMT Core on deck (17° 08.983 62° 13.880 557 m)

72 cm recovered JC83-GC-11-

1840 GMT STATION 50: Gravity Core 12 (17° 08.983 62° 13.880 557 m); 3m barrel

Far north site on open seafloor – repeated deployment ('site 03')

1853 GMT Gravity core on seabed (17° 08.993 62° 13.881 557 m)

Pull out 3.39t; @45 m/min

1910 GMT Core on deck (17° 09.001 62° 13.883 557 m)

No recovery – washed out?

GRAVITY CORE	**lat**	**long**	**depth**
GIS core site 05 *Antigua collapse* **STATIONS 45 & 46**	*17.01.145*	*62 06.529*	***575***
GIS core site 04 *Antigua collapse* **STATIONS 47**	*16 58.522209*	*62 03.398561*	***590***
GIS core site 03 northernmost core **STATIONS 48,49 & 50**	17 08.997398	62 13.904521	**554**

10. SUMMARY OF CORE DATA

Core Name	Station	Location	Water Depth	Length
JC_83_MC01	STATION Megacore 1	16° 39.950; 62° 14.513	641 m	17 cm
JC_83_MC02	STATION 3 Megacore 2	16° 39.512; 62° 13.605	658 m	28 cm
JC_83_MC03	STATION 6 Megacore 3	16° 38.182; 62° 14.747	763 m	38 cm
JC_83_MC04 (tube 1)	STATION 7: Megacore 4 at 'Site 4'	16° 33.224; 62° 16.688	982 m	40 cm
JC_83_MC04 (tube 2)	STATION 7: Megacore 4 at 'Site 4'	16° 33.224; 62° 16.688	982 m	42 cm
JC_83_MC05	STATION 8: Megacore 5 no core just residual bag at 'Site 5'	16° 36.974; 62° 19.626	611 m	n/a
JC_83_MC06 (tube 1)	STATION 9: Megacore 6 at 'Site 6'	16° 33.690; 62° 22.500	733 m	13 cm
JC_83_MC06 (tube 2)	STATION 9: Megacore 6 at 'Site 6'	16° 33.690; 62° 22.500	733 m	28 cm
JC_83_MC06 (tube 3)	STATION 9: Megacore 6 at 'Site 6'	16° 33.690; 62° 22.500	733 m	31cm
JC_83_MC07	STATION 10: Megacore 7 at 'Site 7' IODP U1396	16° 30.488; 62° 27.097	733 m	59 cm
JC_83_MC08	STATION 11: Megacore 8 'Site 7' IODP U1396	16° 30.490; 62° 27.100	787 m	37 cm (Pete to check label – says Megacore 7)
JC_83_MC09	STATION 19: Megacore 9	16° 39.466; 62° 13.602	663 m	32 cm
JC_83_MC10	STATION 20: Megacore 10	16° 39.106; 62° 13.871	703 m	18 cm
JC_83_MC11	STATION 21: Megacore 11	16° 38.587; 62° 14.303	745 m	35 cm
JC_83_MC12	STATION 22: Megacore 12	16° 39.227; 62° 12.742	664 m	24 cm
JC_83_MC13	STATION 23: Megacore 13	16° 39.882; 62° 13.219	592 m	11 cm
JC_83_MC14	STATION 24: Megacore 14	16° 40.164; 62° 13.047	528 m	18 cm
JC_83_MC15	STATION 29:	16° 35.799; 62° 15.678	872 m	39 cm

	Megacore 15			
JC_83_MC16	**STATION 30: Megacore 16**	**16° 36.887; 62° 15.256**	**828m**	**37 cm**
JC_83_MC17	**STATION 31: Megacore 17**	**16° 40.688; 62° 15.322**	**652m**	**24 cm**
JC_83_MC19	**STATION 34: Megacore 19**	**16° 39.097 62° 16.537**	**758m**	**25 cm**
JC_83_MC16 (tube 1)	**STATION 35: Megacore 20**	**16° 40.352 62° 19.012**	**878 m**	**24 cm**
JC_83_MC16 (tube 2)	**STATION 35: Megacore 20**	**16° 40.352 62° 19.012**	**878 m**	**35 cm**
JC_83_GC04	**STATION 41: Gravity Core 4**	**16° 58.158; 62° 06.817**	**662 m**	**~50 cm**
JC_83_GC05	**STATION 42: Gravity Core 5**	**17° 02.207; 62° 14.531**	**619 m**	**~50 cm**
JC_83_GC06	**STATION 43: Gravity Core 6**	**17° 02.270 62° 14.531**	**619 m**	**~50 cm**
JC_83_GC11	**STATION 49: Gravity Core 11**	**17° 08.984 62° 13.880**	**558 m**	**~50 cm**
JC83-83_VC01	**STATION 15: ISIS ROV DIVE 213:**	**16° 40.172°; 62 05.234**	**967 m**	**80 cm**

11. SUMMARY OF ROV DIVES

AREA 1: Offshore St Patricks – SE of Montserrat – in area where surge went offshore

Dive 208 (aborted)

Dive 209 – 650m water depth off St Patricks, SE Montserrat

- **Summary:** Large areas of rather flat seafloor with pervasive rippled fine sand, in some places there are large (~1-3m) blocks of volcanic material sitting on top of this rippled sand. We also saw black tree branches sitting on the sea floor in a couple of places.
- Initially large expanses of ripped fine sand on flat sea floor. Then we took vibracore. Small (< 1 m) volcanic blocks on sand surface. Wood lying on flat rippled sand. Larger 1-3m blocks on flat sand. One block is coral.

Dive 210 – 760m water depth further offshore St Patricks, SE Montserrat

- **Summary:** Large expanses of fine sandy seafloor with pervasive ripples. No blocks seen here.
- More flat areas of pervasively rippled fine sand, perhaps finer than dive 209. More pieces of wood lying on sandy sea floor. Took vibracore. NO blocks

Dive 214 – reoccupies same location as Dive 210

- **Summary:** Large expanses of fine sandy seafloor with pervasive ripples. No blocks seen here.

Dive 215 - – reoccupies same location as Dive 210 and 214

- **Summary:** Large expanses of fine sandy seafloor with pervasive ripples. No blocks seen here.

Area 2 – recent pyroclastic flow lobes; offshore Tar River, E of Montserrat

Dive 212 – 920m water depth offshore Tar River - traverses toe of 100m high ridge formed bu continuation of 1995-recent pyroclastic flows.

- **Summary:** Large areas of rippled fine sand (surprisingly few blocks...) and areas of 1-5m scale blocks. Blocks mainly dark dome rock / andesite with mafic inclusions, but one white block (carbonate??).
- Expanses of rippled fine sand with occasional 1-4m scale volcanic blocks. Dome material. Blocks draped by fine sand. Surprisingly sandy over large areas (some areas lack any blocks). Took vibracore. Winnowed moats around blocks show presence of sustained oceanic currents. White block (carbonate??) plus dark volcanic blocks draped by fine dark sand. Dark blocks seem to be dome rock, blocks become more common. ~5m block of dome rock.

Dive 218 – 790m on the southern side of the recently emplaced pyroclastic flow ridge.

- **Summary:** Again surprisingly sand rippled sea floor with clusters of isolated blocks.
- Large expanse of flat rippled seafloor. Occasional blocks of dark volcanic material, draped by sand.

Dive 219 – long transect up inferred flow path of Feb 2010 collapse event.

- **Summary:** The start of line on Deposit has draped blocks, and some good exposures of blocks. But most of rest of track as you head up slope towards island is flat rippled sand with few blocks.
- Starts at bottom of slope on large expanse of rippled fine sand. Isolate blocks of volcanic material. Some breccias – hydrothermally altered?
- White layer (hemipelagite?) under 5cm of dark sand from recent eruptions. Overlain by an angular dome block. Clusters of angular dome rocks from recent eruptions. Some volcanic blocks embedded in hemipelagic mud.
- Good exposure showing thin 1-4 cm of dark sand from recent eruptions underlain by ~40cm of hemipelagic mud – then a ~40cm layer of pebby-granule dark volcanic material. Probably one of Jess' events. Note hemiplegic mud interval has lots of embedded volcanic material (including large angular blocks).
- Large breccias block – altered?
- Then off to side of blocks (deposit 1) area – in flat expanses of rippled sand on seafloor. Wood.
- Lots of flat rippled sand – as you head upslope

Area 3 - Megablocks offshore Tar River, E of Montserrat

Dive 213 – 960m on the very large southern mega block (we did get a 45 cm ROV-vibracorer here)

- **Summary:** Mega-block is draped with at least 45cm fine sand/mud, with occasional 1-2 m blocks of rather dark coloured volcanic rock.
- fine rippled sand . Clump of displaced coral. Took core. Clumps of coral on dark blocks – poking out of sand. Blocks rounded and look dark (darker than dome rock?) 20-45cm + hemiplegic drape.

Dive 216 – aborted – RESON swath system packed in...

Dive 217 – 1020m on the very large 'Wembley-sized' eastern mega block

- **Summary:** Mega-block comprises many ~m scale blocks with variable composition, including limestone. Seafloor around megablock is rippled sand. The area on landward side of megablock is characterised by very angular blocks of dome rock. Some very good exposures...
- Flat rippled sea floor in area around block. Clusters of White very angular blocks (50cm) on sea floor – limestone has fossils (or hemipelagic mud??). Moved to 1m high exposed escarpment with hemiplegic mud (?) interbedded with four 1-10cm sand (tephra) layers. Probably sequence in Jess' cores from JCR123. Can see that the recent eruptions have produced thin (~5-10cm) layer of dark sand below seafloor. Underlying hemiplegic mud seems scoured (by later flows or ocean currents). Unclear what formed this escarpment....
- Large area of flat rippled sand until reach foot of block. White 1m block draped by sand – block has conglomeratic inclusions? Also adjacent black block of volcanic material. Cluster of dark angular volcanic blocks with hydrothermally altered (red stained material).
- Very angular (dome) volcanic blocks in light/white mud matrix – hp? Spectacular exposures of various dark hues of angular volcanic blocks, and white blocks
- Evidence of ~30-40cm white layer draping blocks and immediately below thin sand from recent eruptions. Hemipelagic drape?
- Wide expanse of flat rippled sand again on seafloor on other side of mega-block.
- Returning to upslope side of megablock. Dark dome angular blocks (much more consistent composition than seem earlier in dive) and underlying white layer (bioclastic turbidite or more likely hemipelagite).
- Block of red hued breccias – hydrothermally altered? Area of homogeneous composition (dome rock) and very angular blocks.

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