**School of Ocean & Earth Science**

**University of Southampton**

# RRS James Cook Cruise 18 (JC18)

$3^{rd}$ – $16^{th}$ December 2007

Montserrat, WI

# Impact of the Early Diagenesis of Sub-aerial Volcanic Material in the Marine Environment

*Principal Scientist*

MR Palmer

2008

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## 1. SCIENTIFIC PERSONNEL

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| Catherine Beswick | University of Southampton |
| Thanos Gritzalis | University of Southampton |
| Debbie Hembury | University of Southampton |
| Will Homocky | University of Southampton |
| Morgan Jones | University of Southampton |
| Rachel Mills | University of Southampton |
| Andy Milton | University of Southampton |
| Ellen Moon | University of Southampton |
| Caroline Peacock | University of Southampton |
| Damon Teagle | University of Southampton |
| Gary Fones | University of Portsmouth |
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| Malcolm Hart | University of Plymouth |
| Alberto Naveira-Garabato | University of Southampton |
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| Chris Fallows | NERC |
| Jeff Benson | NMF ops |
| Colin Day | NMF ops |
| Paul Duncan | NMF ops |
| Jez Evans | NMF ops |
| Alan Sherring | NMF ops |
| Darren Young | NMF ops |

## 2. SHIP'S PERSONNEL

| | |
|---|---|
| P Gauld | Master |
| J Mitchell | Chief Officer |
| R Clarke | Second Officer |
| A Kilkaldy-Willis | Third Officer |
| M Holt | Chief Engineer |
| A Muravjov | Second Engineer |
| A Stevenson | Third Engineer |
| T Levy | Deck Engineer |
| P Parker | Senior ETO |
| P Lucas | Purser |
| M Myers | Systems Manager |
| G Lewis | CPO Deck |
| M Harrison | CPO SC |
| R Spencer | PO Deck |
| J Smyth | ERPO |
| C Cooney | AB |
| D Loveridge | AB |
| S Day | AB |
| A Cantile | AB |
| S Nagle | Head Chef |
| L Sutton | Chef |
| P Robinson | Steward |
| D Hope | Catering Assistant |

## 3. ITINERARY

Sailed St. John's, Antigua 1700 3rd December 2007

Arrived science area 1900 3rd December 2007

Departed science area 2100 15th December 2007

Docked St. John's, Antigua 1000 16th December 2007

## 4. OBJECTIVES

The major objective of this cruise was to test the hypothesis that early diagenetic alteration of recent, subaerial, volcanogenic material in the submarine environment has a significant impact on the global biogeochemical cycles. To this end, NERC funded a 13 day research cruise around Montserrat. The island of Montserrat was chosen as it has been the site of active volcanism since 1995, with ~90% of the products this phase of volcanism already having been transported to the surrounding ocean. In addition, there is a wealth of data concerning volcanic activity on Montserrat, enabling the results of our study to be placed in a well constrained context.

During this cruise we sought to collect sediments from the seafloor using various coring devices (gravity core, box core, mega core). Pore waters were extracted from the sediments (collected from box cores and mega cores) by centrifugation. These pore waters were preserved for transport back to Southampton University and subsequent geochemical analysis. Pore water profiles of dissolved oxygen and redox conditions were measured on board ship using micro electrodes. In addition, DGT and DET gel probes were also deployed in sediments recovered from box cores and mega cores. These probes were fixed and returned to Portsmouth University for subsequent analysis. To complement the pore water studies, a limited number of water column samples were taken using the combined rosette and CTD.

A secondary objective of the cruise was to map the distribution of volcanogenic material in the upper 1 metre of sediments around the island. This work augments cruise 123 of the James Clark Ross, which used vibro-cores to take long (up to 8 m) cores to study the history of volcanism on Montserrat. However, the vibro-cores do not preserve the upper sediments that contain products of the most recent phase of volcanism.

A related aspect of this sedimentological work involved scientists from Plymouth University. This objective was to study the foraminiferal faunal assemblages within the sediments to establish the origin and age of volcanogenic and carbonate turbidites and to examine the nature of early foraminiferal colonisation of volcanogenic sediments.

The study of volcanogenic sediment distribution also included swath bathymetry surveys of underwater features related to subaerial and submarine collapse events.

Space was also made available on JC18 for two independent research projects. One involved a scientist from the University of East Anglia collecting aerosols related to volcanism on Montserrat. The other project involved testing a piece of equipment designed to measure turbulence in the water column.

Finally, we were joined by Mr. Christopher Fallows, who is leading the Discovery replacement project, and who joined the cruise to gain experience of working conditions on a research vessel.

## 5. NARRATIVE

### 5.1 Diary

*Saturday 1st December*

The bulk of the scientific party joined the ship in the evening. A few hours were spent unpacking and making introductions.

*Sunday 2nd December*

The scientific party (assisted by NMF personnel and the ship's crew and officers) completed set up of the scientific and sampling apparatus. Meetings were held between the senior scientists and officers to run over the plans for the cruise. The scientific party completed the signing on process and received a safety briefing from the Purser.

*Monday 3rd December*

All scientific preparations were completed during the early morning in the expectation of sailing before noon. Unfortunately, it had not been possible to bunker the ship the previous day, it be a Sunday and this being Antigua. There was then a delay in bunkering on Monday, possibly related to the fact that there were several large cruise ships in port. Further, when bunkering did eventually start, the fuel hose was only capable of delivering a low rate of flow. Hence, we were unable to leave port before 17:30. Fortunately, the delay did not impact the overall operations of the ship (*Recommendation 1*).

We travelled to Station 1 (16$^{o}$57'N, 62$^{o}$10'W, water depth 710 m) located in a saddle between Antigua and Montserrat. After running the bottom profile over site the 1 m gravity core (JC18-1-GC1) was deployed. Approximately 40 cm of tan-grey carbonate ooze recovered. The core was split for logging. The poor recovery may be related to the sandy nature of the sediments. The bottom currents tend to winnow the fines from the sediments and leave behind a coarse foram and pteropod sand.

The box core (JC18-1-BX) was deployed at the same site and returned approximately one third full. The top of the corer did not seal and the bottom spade did not fully swing across. As a result water gushed through and compromised the sample. ~100 $cm^3$ was taken for microbiological incubation and an archive sample was taken.

*Tuesday 4^th December*

The CTD was readied for deployment at Site 1. During winch operations the CTD cable jumped the sheeve and was damaged. This required the cable to be re-terminated and load tested prior to the next deployment. In addition, the CTD dropped suddenly about 0.5 m so that a near miss incident report was filed. It should be noted, however, that no personnel were in any danger during the incident.

We left Station 1 and travelled to Station 2 (16$^o$50'N, 61$^o$52'W, water depth of 700 m). This site is located in an embayment ~35 km ENE of the volcano and was expected to contain foraminiferal ooze, carbonate turbidites, and possibly recent ash fall out. The sound velocity profiler was deployed to calibrate the EM120 and sub-bottom profiler.

The 1 m gravity core was deployed (JC18-2-GC(1)) and ~12 cm of light tan sandy carbonate ooze was recovered, but there was little penetration. The 1 m gravity core was redeployed (JC18-2-GC(2)), but despite running the gravity core run in at 100 m/min no sediment was recovered – most probably because of the sandy nature of the sediments.

The box core was then deployed (JC18-2-BX). Very little pull out strain was observed and only ~20 cm of disturbed sandy carbonate sediment was recovered. Hence, we decided not to retain any of this sediment. Again, it was apparent that the corer had not sealed properly.

The 6 m gravity core was deployed (JC18- 2-GC6), but the strain gauge indicated that the core bounced on the sandy bottom and no core was recovered.

The mega core was deployed with four tubes (JC18-2-MC). One of the tubes was recovered with an intact sediment core ~25 cm in length. The sediment appeared to consist of homogenous, tan, foraminiferal ooze. The other three tubes had not sealed properly at the bottom – probably due to the sandy nature of the sediment. This led to air bubbling through the sediment in these tubes. The intact tube was used for pore water analysis. One of the other tubes was used for microbiological analysis and another was used for faunal analysis. The contents of the remaining tube were discarded.

The turbulence meter was deployed (JC18-2-TM), with the deployment and recovery proceeding smoothly. Overall, the whole operation took about one hour.

We left station 2 and headed towards start of a swath survey (Point A 62$^o$05.87'N, 16$^o$46.63'W; Point B 62$^o$06.00'W, 16$^o$48.50'N; Point C 62$^o$08.75'W, 16$^o$49.08'N; Point D 62$^o$08.16'W, 16$^o$47.42'N; Point E 62$^o$07.25'W, 16$^o$51.66'N). This swath was designed to examine whether the indentation in the shelf slope in the north east of the island was the result of an undersea slope failure that may have been the origin of the carbonate turbidites identified during JCR123. The swath was not processed on board ship, but the screen images appeared to show several scarp features consistent with slope failure.

We then travelled to Station 3 (62$^o$07.25'W, 16$^o$51.66'N, 725 m water depth), located ~10 km from the NE shore of the island. The sediments at this station were expected to consist largely of background carbonate sediments. The sub-bottom profiler was run over the proposed site and a flat area was identified.

The 6 m gravity core was deployed (JC18-3-GC6), but there was a low pull out on the strain meter and no sediment was recovered.

The mega core was deployed with four tubes (JC18-3-MC(1)). The strain meter showed a 2.1 tonne pull out, and the mega core returned with 4 intact cores, each containing ~30 cm of sediment. The sediment consisted of a 1-2 cm dark tan layer (volcanogenic?) with a sharp boundary overlying light tan carbonate rich sediments. Cores were taken for microbiology, gel probes $O_2$/Eh micro-electrodes study (unfortunately an error during sub-sampling meant this core was lost) and the final core was taken for faunal and sedimentological study.

The mega core was redeployed at this site (JC18-3-MC(2)). The strain meter showed a 2.2 tonne pull out, and the corer returned with 4 intact cores, each containing ~35 cm of sediment with same features as previous core. One core was taken for pore water extraction and one for $O_2$/Eh microelectrode study.

We travelled to Station 4 (16$^{o}$49'N, 62$^{o}$03'W, water depth of 820 m). The site was located ~12 km NE of volcano – north of the debris field – and was expected to contain carbonate sediments, carbonate turbidites, and possibly recent ash fall out. The sub-bottom was run over the proposed site and a flat area was identified.

The 6 m gravity core was deployed (JC18-4-GC6), but the strain meter suggested that corer bounced on touch down. Approximately 35 cm of carbonate-rich sediment was recovered. The core was logged and archived.

The mega core was deployed (JC18-4-MC) and four tubes with 40 cm of sediment were recovered. The upper 2-3 cm consisted of dark brown volcanogenic sediment overlying carbonate. One core was split, archived and bagged, one was taken for faunal analysis, one was taken for rhizon sampling and one was taken for $O_2$/Eh microelectrode study.

*Wednesday 5$^{th}$ December*

The new CTD cable termination was tension tested and passed fit for use. The CTD was then deployed at Site 4 to a depth of 811 m (~10 m above bottom). Samples were taken for dissolved $O_2$ and dissolved Mn at 811 m (deepest sample), 650 m (oxygen minimum) and 280 m (base of thermocline).

We left Station 4 and travelled to Station 5 (16$^{o}$43'N, 62$^{o}$03'W, water depth 1025 m). This site is located level with the Tar River Valley fan at distance of ~10 km from shore and was expected to contain relatively coarse grained volcanogenic material from recent dome collapse events. The sub-bottom was run over the proposed site and showed a blocky bottom. Hence, the site was moved slightly south (16$^o$42.6'N, 62$^o$03'W, water depth 1042 m).

The 6 m gravity core was deployed (JC18-5-GC6), but the tension gauge suggested that the core had toppled over and no sediment was recovered.

The mega corer was deployed (JC18-5-MC(1)), but only a small amount of sediment was recovered in the tubes and the sample was discarded.

The box corer was deployed (JC18-5-BX), but again no sediment was recovered.

The CTD was deployed (JC18-5-CTD). Samples were taken for dissolved $O_2$ and dissolved Mn at 1038 m (deepest sample), 577 m (oxygen minimum) and 126 m (thermocline base).

The mega core was deployed (JC18-5-MC(2)). Two tubes were recovered with ~10 cm of volcanogenic sediment, but the stratigraphy was not preserved. Sub-samples were taken for study of the Fe oxidation state and microbiology. The lack of success in recovering cores at this site was not surprising as the grain size is relatively coarse (sand) close to the dome collapse entry point.

We travelled to Station 6 (16$^o$40.5'N, 62$^o$00'W, water depth 1088 m). The objective of this site was to dredge a seamount/undersea volcano. The sub-bottom profiler was run to 16$^o$41'N, 61$^o$58'W and a depth of 725 m. The dredge was lowered at 16$^o$40.4'N, 61$^o$58.3'W in 911 m of water. The ship then ran at 0.5 knots for ~500 m to 16$^o$40.63'N, 61$^o$58.13'W in a water depth of 725m. The were only a few sponge fragments in the chain bag, and the bucket was full of grey sand and carbonate sediment, plus a few pieces of carbonate hard ground.

We travelled to Station 7 (16°41'N, 62°02'W, water depth 1080 m). This site lies in the path of turbidites/debris flows generated from dome collapses down the Tar River Valley. Hence, volcanogenic sediments were expected at this site. The sub-bottom profiler was run across the site and a flat bottom was selected.

The mega corer was deployed (JC18-7-MC(1)). One tube contained ~5 cm of volcanogenic sediment, but the rest of the tubes failed to collect any sediment. The mega corer was redeployed (JC18-7-MC(2)) and this time, all four tubes collected ~10 cm of disturbed sediment. These were sampled for fauna and microbiology.

*Thursday 6th December*

Following the lack of success with the previous mega cores, we moved slightly south to a new site (16°40.96'N, 62°02'W, water depth 1077 m) and deployed the box core (JC18-7-BX). Approximately 20 cm of disturbed volcanogenic sediment was recovered. One sub sample was taken for archive, one for rhizon pore water extraction and one for faunal studies.

We travelled to Station 8 (16°38.7N, 62°02'W, water depth 1110 m). This site is located further south along track of the Tar River debris flow/turbidites and was expected to contain finer grained sediments that should be easier to sample. It was noted that the flaps on the top of the box corer were not sealing correctly, which may have contributed to some of the coring failures. These were modified in an attempt to provide a tighter seal. A sub-bottom profile was run across the site and a flat bottom was selected.

The mega corer was deployed (JC18-8-MC(1)), but only two of the four cores worked, and these collected ~30 cm of disturbed volcanogenic sediment. The mega core was redeployed (JC18-7-MC(2)). This time, three of the four tubes were filled with ~40 cm of sediment, consisting of ~30 cm of volcanogenic sediment overlying carbonate sediment. One tube was taken for rhizon pore waters, one for gel probes, one for archive and one for sedimentology.

We travelled to the Tar River Valley fan to carry out a swath survey. The object of this exercise was to image the deposits formed from the 2006 dome collapse event. The swath was not processed on board, but the data was recorded for post-cruise analysis.

*Swath Way Points*

A: 16°44.00'N, 62°07.50'W B: 16°41.50'N, 62°07.50'W ~700 m contour

C: 16°41.00'N, 62°06.25'W D: 16°45.00'N, 62°06.25'W ~850 m contour

E: 16°45.50'N, 62°05.00'W F: 16°40.00'N, 62°05.00'W ~950 m contour

G: 16°40.00'N, 62°03.25'W H: 16°45.50'N, 62°03.25'W ~1000 m contour

We left the swath area, returned to Station 8 and deployed the box core (JC18-8-BX). There was a 4.35 tonne pull out on strain meter – indicating a good core. Approximately 25 cm of sediment was recovered (20 cm of volcanogenic sediment overlying carbonate-rich sediment). One sub sample taken for archive, one for fauna, one for $O_2$/Eh microelectrodes, and one for pore water extraction by centrifuge.

We travelled to station 9 (16°36.5'N, 62°02'W, water depth 1133 m). This station continues the southern passage of the Tar River debris flow/turbidites. The sub-bottom profile was run across the site and a flat bottom was selected.

The turbulence meter was deployed and recovered while the pore waters were being processed from the previous site.

The mega core was deployed (JC18-9-MC) with six tubes. One tube failed, but the other five collected ~30 cm of sediment (consisting of 25 cm volcanogenic sediment overlying 5 cm of carbonate). One tube was taken for rhizon pore waters, one for gel probes, one for fauna, and two tubes as a contingency in case the subsequent box core failed.

The box core was deployed (JC18-9-BX) and ~35 cm of intact sediment was recovered, consisting of 20 cm of volcanogenic material overlying carbonate sediment. Two sub cores were taken for iron incubation experiments, one for fauna, two for sedimentary logging, and one for microelectrode study. In addition, a syringe sample was taken for Fe oxidation state studies and a scraping of surface sediments was for microbiological analysis.

*Friday 7th December*

The CTD was deployed (JC18-9-CTD) and samples were taken for dissolved $O_2$ and Mn at 1130 m (deepest sample), 550 m (oxygen minimum zone) and 310 m (base of thermocline).

We then travelled to Station 10 (16°33'N, 62°00'W, water depth 1167 m). This site is further south along the track of the Tar River volcanogenic debris flow/turbidites. A sub-bottom profile was run across the site and a flat bottom was selected.

The mega core was deployed (JC18-10-MC(1)) and when it returned to the deck it was clear that it had been buried above the centre weights. The tubes were full of very fluid volcanogenic mud (~50 cm) underlain by a thin (~5 cm) layer of carbonate sediment.

The 6m gravity core was deployed (JC18-10-GC6(1)), but the core came up empty and it appeared that all the sediment had simply washed out of the barrel. The 6 m gravity core was redeployed (JC18-10-GC3(2)), but despite being run in at 100 m/min it still returned empty of sediments.

The turbulence meter was then deployed (JC18-10-TM). The deployment and recovery went smoothly apart from the loss of one of the "toothbrushes" (used to provide drag) during recovery.

The mega corer was redeployed (JC18-10-MC(2)) at this site. To try and stop the mega corer sinking into the mud we fitted wooden planks around the base of the frame and reduced the weight. The core still sank, but not as much as during the first deployment at this site. Five of the six tubes returned with ~50 cm of sediment, consisting almost entirely of very fine-grained (sub 65 μm) volcanogenic material with a liquid-like texture, underlain by ~5 cm carbonate at the base of the core. One core was taken for $O_2$/Eh microelectrode study, one for gel probes, one rhizon pore waters, one for fauna and one for archive.

We left Station 10 and headed to the start of a swath survey. The object of this survey was to define the characteristics of the depo-centre that lies at the southern end of the sea floor valley leading from the Tar River Valley fan. The survey was not processed on board, but the raw images showed a generally flat depo-centre with a moat along the western margin.

After the swath survey we travelled to Station 11 ($16^o$29'N, $61^o$57.5'N, water depth 1203 m). This site is at the northern margin end of the depo-centre.

The mega corer was deployed (JC18-11-MC). Five out of the six tubes collected sediment, consisting of 1-3 cm of volcanogenic material overlying ~20 cm of carbonate. One core was taken for gel probes, one for $O_2$/Eh microelectrodes, one for archive and sedimentology, and one for faunal analysis.

*Saturday 8$^{th}$ December*

The 6 m gravity core was deployed (JC18-11-GC6), and returned with 56 cm of sediment. The upper 12 cm consisted of volcanogenic material overlying carbonates, with the latter containing several volcaniclastic layers.

From Station 11 we travelled to the start of the swath survey designed to complete coverage of the depo-centre. The raw data confirmed the features identified in the first half of the survey.

At the end of the survey we arrived at Station 12 ($16^o$24.8'N, $61^o$54.5'N, water depth 1217 m). This marks the deepest part of the basin, apart from the moat to the west of the basin.

The mega corer was deployed (JC18-12-MC) and all six of the tubes collected ~30 cm of fine grained volcanogenic material overlying ~5 cm of pelagic ooze. One core was taken for gel probes, one for $O_2$/Eh microelectrode study, two cores for archive, one for faunal analysis, and one for pore water separation by centrifuge.

The turbulence meter was deployed (JC18-12-TM) and successfully recovered.

The gravity core was deployed (JC18-12-GC6) and returned with ~60 cm of sediment, consisting of ~30 cm of recent volcanogenic material overlying carbonate sediments that included the 2kyr Montserrat bioclastic turbidite. A fragment of large silicified sponge was located at the base of the core and may have stopped it penetrating further.

The CTD was deployed (JC18-12-CTD) and samples for nutrients were taken at depths of 1217, 806, 553, 504, 489, 379, 253, 143, 53, and 14 m. Samples for dissolved oxygen and Mn were taken at 1217 m (bottom), 553 m (oxygen minimum) and 253 m (thermocline base).

The box core was deployed (JC18-12-BX). The core contained ~60 cm of sediment, consisting of ~30 cm of very liquid, fine-grained, mud overlying coarser volcanogenic material and a ~5 cm base of carbonate sediments. One sub-core was taken for pore water centrifuge extraction, one for rhizon pore water extraction, one for gel probes, one for $O_2$/Eh microelectrode study, and one for fauna and sedimentology study. A 0.5 m core barrel was also filled with the fine grained volcanogenic material for incubation experiments in Southampton.

The 6 m gravity core was redeployed (JC18-12-GC6(2)). The core consisted of ~60 cm of sediment with the same stratigraphy as first GC at this site.

We then travelled to Station 13 (16$^{o}$31'N, 62$^{o}$05.5'W, water depth of 984 m). This site is located on the ridge extending south east from Montserrat as was not expected to contain any bottom-transported volcanogenic sediment.

The turbulence meter was deployed (JC18-13-TM) and recovery without any problems.

The mega corer was deployed (JC18-13-MC). All 6 tubes contained ~25 cm sediment, consisting of 1-3 cm volcanogenic (ash?) sediment overlying pelagic carbonate. One core was taken for centrifuge pore water, one for $O_2$/Eh microelectrode study, one for fauna, one for archive, and one for gel probes.

*Sunday 9th December*

The CTD was deployed (JC18-13-CTD)and samples were taken for dissolved oxygen and Mn at the deepest site (954 m), the oxygen minimum (540 m) and the base of the thermocline (340 m).

The gravity core was deployed (JC18-13-GC6) and ~40 cm of sediment was recovered, consisting of thin ash layer overlying carbonate sediments.

The box core was deployed (JC18-13-BX). The core contained ~40 cm of sediment, consisting of 1-2 cm of volcanogenic material overlying carbonate sediments. One sub core was taken for rhizon pore water, one for centrifuge pore waters, one for dissolved $O_2$/Eh electrode analysis and one for faunal and sedimentological analysis.

We then left this station to start a brief swath survey of the White River valley deposits. Following this survey we chose a location for Station 14 ($16^o$37.3'N, $62^o$15.6'W, water depth 805 m).

The gravity corer was deployed (JC18-14-GC6). On recovery it was observed that the barrel was bent. After some effort the liner was extracted and was observed to contain ~60 cm sediments, consisting of ~10 cm volcanogenic sediment overlying carbonate sediment.

Due to problems with the gravity corer (see above) and a technical hitch with the turbulence meter we decided to carry out a swath of the debris flow off of Plymouth to identify a site for Station 15.

We then returned to station 14 and deployed the mega core (JC18-14-MC(1)), but no sediment was recovered. The mega core was redeployed (JC18-14-MC(2)) and four cores were recovered containing ~40 cm sediment, consisting of ~10 cm of volcanogenic sediment overlying carbonate sediment. One core was taken for centrifuge pore waters, one for $O_2$/Eh microelectrode, one for gel probes, and one for fauna and sedimentology analysis.

We then travelled to Station 15 (16$^o$35'N, 62$^o$17'N, water depth 908 m). This site is on a southwest of the island and it was thought that it might contain distal deposits from the White River valley.

The gravity core was deployed (JC18-15-GC6). The core contained ~60 cm of sediment, comprising an upper ash layer (that was largely washed out), underlain by tan carbonate grading into grey sandy carbonate.

The turbulence meter was deployed (JC18-15-TM) and recovered without incident.

The mega corer was deployed (JC18-15-MC). Four tubes contained ~40 cm of sediment, comprising 6 cm of volcanogenic material overlying carbonate sediment. One tube was taken for $O_2$/Eh microelectrode study, one for gel probes, one for sedimentology and fauna, and one for pore water centrifuge.

The CTD was deployed (JC18-15-CTD) and samples were taken for dissolved $O_2$ and Mn at the bottom (905 m), the oxygen minimum (557 m) and the thermocline base (280 m).

*Monday 10$^{th}$ December*

We travelled to Station 16 (16°38.61'N, 62°16.97'W, water depth 706 m). We anticipated that this site might contain lahar-type sediments delivered down the Belham Valley.

The 3 m gravity core was deployed (JC18-16-GC3), returned empty, and with a large dent in the fin.

We abandoned this site and travelled to Station 17 (16°36.44'N, 62°21.26'W, water depth 804 m). This site was moved from a prominent hill after the sub-bottom profiler showed a rocky bottom. We anticipated that this site should contain the thickest air fall deposits.

The gravity core was deployed (JC18-17-GC). Although no core was recovered, the core catcher contained coarse bioclastic sand.

The mega corer was deployed (JC18-17-MC(1)). Four full tubes were recovered, containing ~50 cm of sediment, consisting of 1-5 cm of volcanogenic material overlying layered carbonate sediments. One core was taken for $O_2$/Eh microelectrode and microbiology study, one for gel probes, one for sedimentology and faunal analysis, and one for pore water by centrifuge.

The turbulence meter was deployed (JC18-17-TM) and recovered smoothly.

The mega corer was redeployed (JC18-17-MC(2)). Four tubes were recovered with ~30 cm of sediment, consisting of ~1 cm of volcanogenic sediment overlying carbonate sediments. Three of the cores were disturbed by bubbles during recovery. One core was taken for gel probes, one for microbiology, and one for fauna and sedimentology. A live starfish was found in one sample.

We travelled station 18 at 16°30.5'N, 62°27'W in a water depth of 787 m. This site is further downwind from the volcano, so we expected to see the air fall deposits thinning.

The 6 m gravity core was deployed (JC18-18-GC6). No significant pull out was observed and only a handful of coarse bioclastic sediment was recovered from the core catcher.

1202: The mega corer was deployed (JC18-18-MC). The cores contained ~25 cm of largely carbonate sediment. Two of the four cores were intact and two were compromised by bubbles. One core was taken for centrifuge pore waters, one for gel probes, and one for faunal analysis.

The turbulence meter was deployed JC18-18-TM and recovered smoothly.

The box corer was deployed (JC18-18-BX). The core consisted of 0.5 cm of volcanogenic sediment overlying 20 cm of carbonate. Two sub-cores were taken for Fe incubation experiments, one for $O_2$/Eh microelectrodes, and one for sedimentology and fauna. A surface sample was taken for microbiology study.

We travelled to Station 19 (16$^{o}$22.70'N, 62$^{o}$34.41'W, water depth 1130 m). This site is further downwind still from the volcano.

The 3 m gravity core was deployed (JC18-19-GC3). The core contained 2.6 m of sediment consisting of many volcanogenic layers within carbonate sediments.

The mega core was deployed (JC18-19-MC). The four tubes contained ~20 cm of sediment, consisting of a thin (0.5 cm) dark layer (volcanogenic?) of material overlying carbonate sediments. One core was taken for pore water, one for $O_2$/Eh microelectrodes and one for fauna and sedimentology analysis.

The turbulence meter was deployed (JC18-19-TM) and recovered without incident.

*Tuesday 11$^{th}$ December*

The CTD was deployed (JC18-19-CTD), and samples were taken for dissolved $O_2$ and Mn at 1131 m (deepest), at 604 m (oxygen minimum), and 104 m (base of the mixed layer).

The 6 m gravity core was deployed (JC18-19-GC6) and 3.65 m of core was recovered. There was identical stratigraphy to the 3 m gravity core in the upper part of the core with volcanogenic layers in carbonate extending to the bottom of the core.

We then started a swath survey with the objective of examining whether the depo-centre described on the GEBCO map (16$^o$25'N, 62$^o$50'W, water depth 2300 m) is a real feature. The swath revealed that there is no depo-centre – simply a continuation of the canyon floor, with a maximum depth of ~1960 m.

We travelled to Station 20 (16$^o$25'N, 62$^o$50'W, water depth 1933 m). This site is roughly in the centre of the canyon and may contain flow deposits of sediments from the west of Montserrat.

The 3 m gravity core was deployed (JC18-20-GC3), but no sediment was recovered.

The mega core was deployed (JC18-20-MC), and ~15 cm of sediment was recovered, consisting of a ~0.5 cm dark layer overlying tan carbonates. One core was taken for fauna, one for archive, one for gel probes, one for $O_2$/Eh electrode microelectrode study and one for microbiology.

The turbulence meter was deployed (JC18-20-TM) and recovered smoothly.

The CTD was deployed (JC18-20-CTD) and sampled over the complete depth range (1946, 1511, 1156, 1006, 855, 562, 403, 276, 152, 102, 52) for nutrients, $O_2$ and Mn.

We travelled to Station 21 (16$^o$21'N, 63$^o$00'W, water depth 1270 m). This is our most distal site from Montserrat and should be the closest to a background core containing no volcanogenic material.

The 3 m gravity core was deployed (JC18-21-GC3) and 2.69 m of hemipelagic carbonate sediment was recovered. There were no obvious volcanogenic layers.

The mega core was deployed (JC18-21-MC) and ~35 cm of sediment was recovered, consisting of ~0.5 cm thick dark layer (volcanogenic?), 15 cm of tan carbonate, and 20 cm of pale carbonate. One core was taken for fauna, one for archive, one core for gel probes, and one for $O_2$/Eh micro electrode study.

The turbulence meter was deployed (JC18-21-TM) and recovery proceeded smoothly.

*Wednesday 12th December*

We travelled to Station 22 (16$^o$27.70'N, 62$^o$38.08'W, water depth 1100 m). This site is close to a Carmon core taken by Le Friant et al in 2002, and we wanted to verify some of their interpretations. A brief swath survey was carried out over the area and the exact core site was selected.

The 6 m gravity core was deployed (JC18-22-GC6), but no sediment was recovered. It was redeployed (JC18-22-GC6(2)) and 45 cm of sediment was recovered, consisting of hemi-pelagic ooze with a thin ash layer at 9 cm.

The mega core was deployed (JC18-22-MC) and 26 cm of sediment was recovered, consisting of 0.5 cm of dark fine-grained ash overlying tan-coloured hemipelagic carbonate-rich sediment. One core was taken for pore water, one for $O_2$/Eh micro electrode study, one for gel probes, one for fauna and one for archive.

The turbulence meter was deployed (JC18-22-TM) and recovered without any problems.

The 3 m gravity core was deployed (JC18-22-GC3) and ~50 cm of sediment was recovered with approximately the same stratigraphy as that recovered in the 6 m core.

We travelled to Station 23 (16$^o$31.6'N, 62$^o$34.6'W, water depth 959 m). This site is close to Station 22 and was selected to try and recover a long enough core to provide a comparison with the Carmon core.

The 3 m gravity core was deployed (JC18-23-GC3) and just over 1 m of sediment was recovered. This sediment consisted of grey-brown bioclastic mud, with no visible ash or volcaniclastics.

The mega core was deployed (JC18-23-MC) and four cores were recovered containing ~25 cm of sediment consisting entirely of brown-grey bioclastic ooze. One core was taken for gel probes, one for $O_2$/Eh micro electrode study, one for archive and one for fauna.

The 6 m gravity core was deployed (JC18-23-GC6), but returned without any sediment and a bent barrel.

We travelled to Station 24 (16$^o$41.7'N, 62$^o$20.00'W, water depth 995 m). This site is also located close to one of the Le Friant et al cores and was again selected by way of comparison. The swath survey revealed a smooth bottom with well stratified sediments.

The 3 m gravity core was deployed (JC18-24-GC3) and returned with 76 cm of sediment, consisting of ~5 cm of volcanogenic sediment overlying grey carbonate ooze.

The mega core was deployed (JC18-24-MC) and returned with all six tubes full of 41 cm of sediment. The core consisted of 8 cm of structured volcanogenic material overlying grey carbonate ooze. One core was taken for pore water, one for $O_2$/Eh micro electrode study, one for gel probes, one for fauna, and one for archive.

*Thursday 13th December*

The turbulence meter was deployed (JC18-24-TM) was recovered without incident.

At this point in the cruise the PSO suffered a serious injury to his knee that left him largely confined to his cabin. Hence, control over the day-to-day operations of the cruise passed to Damon Teagle and Rachel Mills. The injury turned out to be a torn cartilage in the right knee. The second mate administered pain killers and a cold compress, which was all that could be done in the circumstances. Stronger pain killers were prescribed on return of the ship to Antigua and at the time of writing (two months after the cruise) the PSO is making a slow recovery.

We travelled to Station 25 (16°44.00'N, 62°20.31'W, water depth 878 m). This site is located ~10 km off the west coast of the island and was expected to contain ash fall volcanogenic material, together with some slope failure material.

The 3 m gravity core was deployed (JC18-25-GC3) and returned with ~70 cm of sediment, consisting of 5-10 cm of volcanogenic material overlying carbonate ooze.

The mega core was deployed (JC18-25-MC) and returned with six tubes containing 45 cm of sediment. The cores consisted of 9 cm of volcanogenic material (made up of four distinct layers) overlying brown-grey coloured carbonate sediment. One core was taken for $O_2$/Eh micro electrode study, one for gel probes, one for fauna and one for archive.

The turbulence meter was deployed (JC18-25-TM) and recovered without incident.

We travelled to Station 26 (16°44.5'N, 62°29.0'W, water depth 1069 m). This site is located to the west of a large canyon separating Montserrat from the St. Kitts and Nevis platform. Hence, it cannot contain and debris flow from Montserrat and should only contain air fall volcanogenic material.

The 3 m gravity core was deployed (JC18-26-GC3) and was recovered with ~70 cm of sediment, consisting of ~1.5 cm of volcanogenic material overlying grey-tan carbonate ooze.

The mega core was deployed (JC18-26-MC) and was recovered with five of the tubes having fired successfully. The sediment consisted of ~1 cm of volcanogenic material underlain by a pteropod-rich layer, which was in turn overlying red-grey carbonate ooze. One core was taken for $O_2$/Eh micro electrode study, one for gel probes, one for fauna and one for archive.

The turbulence meter was deployed (JC18-26-TM). Unfortunately, this time one of the brushes was lost during recovery. All the spares had been used, so that no more deployments were possible during the cruise.

The CTD was deployed (JC18-26-CTD) and samples were taken for dissolved $O_2$ and Mn at 1069 m (deepest), at 967 m (oxygen minimum), and 202 m (base of the mixed layer).

We travelled to Station 27 (16$^{o}$49.5'N, 62$^{o}$18'W, water depth 926 m). This site is located at the northern end of the canyon separating Montserrat from Redonda, and was expected to consist large of carbonate sediments, possibly with a thin layer of volcanogenic ash fall. A swath survey was undertaken to pick the best site for the core.

The 3 m gravity core was deployed (JC18-27-GC3) and returned with ~120 cm of sediment, consisting of ~12 cm of volcanogenic material overlying carbonate ooze.

The mega core was deployed (JC18-27-MC) and five of the cores fired successfully. The sediment consisted of ~35 cm of very fine-grained liquid like volcanogenic mud (very similar to that recovered at Station 12), overlying ~10 cm of carbonate ooze. It seems almost certain that this material comes from the 2006 dome collapse and was transported by surface currents around the north of the island. One core was taken for rhizon pore waters, one for Fe oxidation state studies, one for $O_2$/Eh micro electrode study, one for fauna and one for archive.

The CTD was deployed (JC18-27-CTD) and samples were taken for dissolved $O_2$ and Mn at 925 m (deepest), at 654 m (oxygen minimum), and 151 m (base of the mixed layer).

*Friday 14th December*

We travelled to Station 28 (16$^o$37.40'N, 62$^o$06.42'W, water depth 1023 m). This site is located to the southeast of Montserrat as we decided to carry out a transect across the valley carrying dome collapse material south-south east from the island.

The mega core was deployed (JC18-28-MC) and recovered with four of the tubes having fired. The sediment consisted of ~15 cm of volcanogenic material, containing 7 graded units, overlying ~30 cm of carbonate ooze. One core was taken for archive, one for fauna and one for $O_2$/Eh micro electrode study.

We travelled to Station 29 (16$^o$37.60'N, 62$^o$04.80'W, water depth 1070 m), located further east along the transect.

The mega core was deployed (JC18-29-MC) and recovered with four tubes. The sediment consisted of ~20 cm of volcanogenic material overlying 15 cm of carbonate ooze. One core was taken for archive, one for fauna and one for $O_2$/Eh micro electrode study.

We travelled to Station 30 (16$^o$39.2'N, 61$^o$59.89'W, water depth 1105 m), located along the transect.

The mega core was deployed (JC18-30-MC), but returned with only water in the tubes. The stand appeared to have fallen over during the deployment.

We travelled to Station 31 (16$^o$39.2'N, 62$^o$00.17'W, water depth 1103 m), located along the transect.

The mega core was deployed (JC18-31-MC), but only three of the cores returned with any sediment, and this consisted of only 5 cm of highly disturbed material.

We travelled to Station 32 (16$^o$39.7'N, 61$^o$57.2'W, water depth 876 m). This site lies ~150 m above the valley floor on the eastern wall on a plateau between two submarine volcanoes. Hence, it is not expected to contain turbidites from the dome collapse debris flows.

The mega core was deployed (JC18-32-MC), and six sediment-filled tubes were recovered. The sediment consisted of ~10 cm of volcanogenic material (most probably from the 2006 collapse event) overlying a further 10 cm of carbonate sediment. One core was taken for archive, one for fauna and one for $O_2$/Eh micro electrode study.

We travelled to Station 33 (16$^o$38.40'N, 62$^o$02.00'W, water depth 1114 m). This site is located in the centre of the valley and was selected for a box core site that would (hopefully) enable us to obtain a large volume of sediment for a variety of studies.

The box core was deployed (JC18-33-BX). The core contained ~35 cm of well layered sediment comprising several layers from the 2006 dome collapse, overlying the 2003 event and possibly the 1998 event. Two sub-cores were taken for archive, one for $O_2$/Eh micro electrode study and two for pore water (one rhizome and one centrifuge). In addition, a number of syringe samples were taken for Fe oxidation state studies.

We travelled to Station 34 (16$^o$36.85'N, 62$^o$07.60'W, water depth 986 m). This site lies on the eastern wall of the valley.

The mega core was deployed (JC18-34-MC) and was recovered with six tubes of sediment. The sediment comprised ~10 cm of volcanogenic sediment overlying ~15 cm of carbonate material. One core was taken for archive, one for fauna and one for $O_2$/Eh micro electrode study.

We travelled to Station 35 (16°39.49'N, 62°13.59'W, water depth 660 m). This site is located off the White River valley and was selected to try and sample the products of the large 1998 lateral blast down this valley.
The 3 m gravity core was deployed (JC18-35-GC3), but returned empty after appearing to have fallen over.

The mega core was deployed (JC18-35-MC) and was recovered with ~15 cm of sediment. The coarse grained base contains charcoal and large blocky fragments – possibly tiles. As this was right at the end of the scientific coring operations the core was simply archived.

*Saturday 15th December*
All NERC operational staff and scientists were stood down overnight in preparation for packing away all the scientific gear. Accordingly, most of the scientists spent the day clearing the laboratories and assisting in loading the containers for off loading in Antigua.

Time was also spent testing the air guns (on deck) and the deploying and recovering the streamer system to be used during JC19.

After completion of these operations the ship hove to off of Antigua overnight.

*Sunday 16th December*
The ship entered port in St. John's Antigua and tied up by 10:30. All scientific personnel disembarked by noon, after completion of immigration formalities.

**5.2 Acknowledgments**
Without exception, every member of the officers, crew, NERC operational staff and scientists aboard JC18 contributed fully towards making this a highly successful cruise.

It has been over 6 years since I led a cruise on a NERC ship and this was without doubt the most professional and dedicated group of individuals I have sailed with - my sincere thanks to you all.

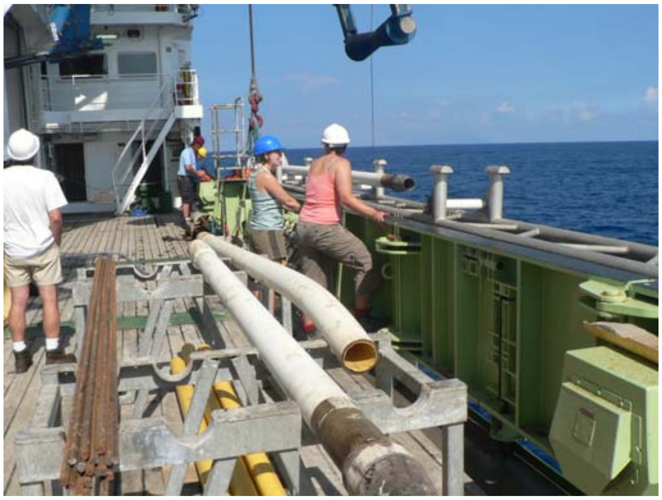
## 6. SAMPLING EQUIPMENT & SAMPLING/ANALYTICAL PROTOCULS

### 6.1 Sampling Equipment

Gravity core

Although this is in theory the most reliable and simplest of the various coring options we employed, it proved to be the least successful. Only 5 cores exceeded 1 metre in length out of ~30 attempts. Most of the cores only recovered a few tens of centimetres of sediment. The main reason for this problem is most likely the sandy nature of much of the sediment. The strong bottom currents lead to winnowing of the sediments and removal of the fine-grained clays and nannofossils. The other problem we had was that it was very hard to interpret the sub-bottom profiler. If the thrusters were in use the signal was heavily degraded, and even when there was no interference on the signal it was not apparent whether the profiler was recording a soft or hard bottom surface (*recommendation 2*).

When the gravity core was operated with the 3 metre or 6 metre barrel it was necessary to deploy and recover it using the cradle. This required the use of the mid-ship crane in association with the coring winch. Unfortunately, the controls on the crane did not allow for the fine adjustment needed for a smooth transfer. This resulted in the gravity core swinging about and clattering into the side of the ship and recovery platform on a number of occasions. As well as being potentially hazardous to the deck crew recovering the core, it could also lead to scarring of the hull (*recommendation 3*).



*Bent core barrel from 3 m gravity core.*

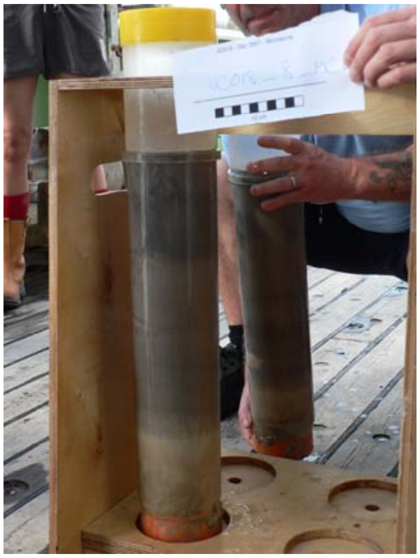
Box core

The SMBA box corer was used during the cruise. The early deployments suffered problems due to the spade not swinging across fully and the top doors not sealing. This resulted in washing out and channelling of the sediments during recovery. However, these problems were soon rectified and the box core yielded large volumes of sediment that allowed multiple sampling of the sediments. There was little that could be done to avoid this problem. My experience has been that the box core often needs tweaking after the first deployment. As our first station was only a few hours out of port, we did not have the luxury of a shake down station to carry out these adjustments.


*Box core from station JC18-8 with multiple sampling tubes inserted. Note, clear water on top indicates good preservation of sediment-water interface.*

Mega corer

The mega corer proved to be by far and away the most successful coring device used on the cruise. There were a few initial problems related to the tubes not sealing properly. This allowed air to bubble through the cores during recovery and destroyed the stratigraphy. However, a few adjustments soon sorted out this problem. The only other problems encountered were when the corer appeared to topple over on the bottom and, when deployed in some particularly soft sediments, the mega corer became completely buried and over-filled the tubes. In the latter case this mega corer was deployed with the weight load reduced and some wooden planks attached to the frame to prevent it sinking. Fortunately, we were operating in relatively calm seas and the cruise was only 13 days long. However, the mega core is more delicate than the other coring devices, so that there would be potential for damage to the mega corer during a longer cruise in rougher water (*recommendation 4*).



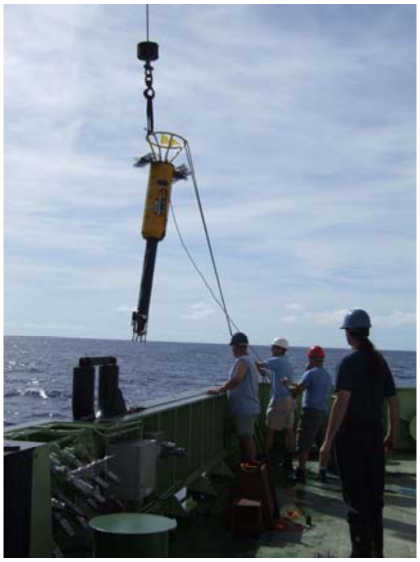
*Fine scale stratigraphy preserved in one of the mega core tubes.*

<u>CTD and rosette</u>

This is a routine piece of equipment in oceanographic operations. The only problem was encountered when the CTD cable jumped the sheeve and was damaged. This required the cable to be re-terminated and load tested prior to the next deployment. Fortunately, no personnel were injured during the incident and the damage was quickly repaired.

<u>Turbulence Meter</u>

This equipment was not an integral part of the science program for JC18. However, we were operating in relatively shallow waters (generally ~1000 metres), so the coring operations proceeded more quickly than we could process the samples. This allowed us time for Dr Alberto Naveira Garabato to deploy his turbulence meter in between coring deployments. In addition, it was deployed off the aft of the starboard deck using the mid-ship crane so there was no interference with preparation of the corers. In general, the deployment and recovery operations went smoothly, but three sets of brushes were lost during recovery, which ultimately prevented further deployments. Dr Garabato is already making plans for adapting the instrument to overcome this problem.



*Deploying the turbulence meter*

**6.2 Sampling/analytical protocols**

6.2.1. Shipboard Incubation experiments

A series of sediment-seawater incubation experiments were conducted to investigate the potential for trace metal fluxes, specifically of Fe, from tephra-rich deposits of the Montserrat marine sediments into the overlying seawater. The episodic resuspension of surface sediments was also undertaken to examine the influence of resuspension on dissolved trace metals in overlying seawater. Finally, sediment pore fluids were sampled using a suite of filter sizes, in order to try and quantify the colloidal component of "dissolved" Fe in these pore fluids.

Two sites were chosen for incubation experiments; station 9 and station 18. Core samples were incubated in a controlled temperature laboratory between 4ºC and 6ºC, using the incubation unit illustrated below. Prior to expelling trapped air between the incubation unit and the seawater, the cavity was flushed with nitrogen gas to minimise the potential for oxygen dissolution from trapped bubbles beneath the incubation unit.

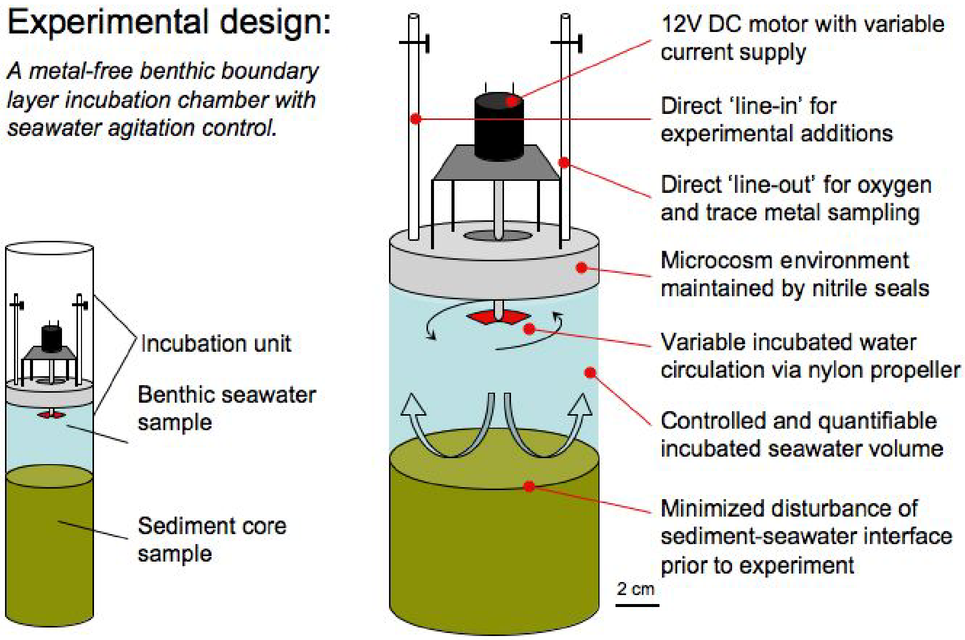



*Illustration of incubation unit design, modified from a design by University of Southern California. The unit is designed to fit directly into a sample mega-core tube, allowing for repeated shipboard incubations of cores with minimal sample interference.*

*Diffusive flux investigation* - Duplicate cores were used from each site with equal sediment depth and overlying water volume. Water agitation was achieved by setting the propellers to a 'low' rotation speed (~30rpm), which produced no visible signs of sediment entrainment in the water column. Trace metal samples were taken every 6 hours after the start of the incubation. The first 5mls of every sample were passed to waste; to avoid mixing of incubated water from the chamber with water left in the hose lines from the previous sample. A 10ml sample was filtered directly into an acid cleaned LDPE bottle, using an Anachem 0.2µm cellulose acetate syringe filter and acid cleaned syringes (without nitrile bungs). Samples were then acidified with 50µl of 6M Q-HCl for post cruise analysis. Oxygen was sampled once every 24 hours for determination by the Winkler titration method. Using a 60ml LDPE syringe, 70ml oxygen samples were drawn immediately after expelling 5mls to waste to clear sample lines. Bubble-free samples were then used to fill and flush a gravimetrically calibrated 30ml glass bottle. Oxygen samples were immediately ‘fixed’ with winker reagents.

*Resuspension experiments* – These were conducted on a single core following the completion of each diffusive flux experiment. 8 samples for trace metals were taken over period of 90 minutes by the same protocol as the diffusive flux investigations. During these experiments the overlying seawater was agitated by a ‘high’ propeller speed (~200rpm) for 20 minutes. During which time the overlying seawater became turbid and laden with re-suspended surface sediment. After resuspension the propellers were returned to a ‘low’ speed (~30rpm). The experiment finished when the seawater appeared to have settled and returned clear, in this case, after 90 minutes.

Two 10cm diameter sub-cores were taken adjacent to each other from JC18-33-BX. These were used for the extraction and filtration of pore waters, using different sized filter membranes in order to assess the trace metal distribution between these size fractions, and quantify the colloidal component of Fe in these pore waters. Cores were sectioned at 1cm intervals for the first 0-5cm depth and then 2cm intervals for 5-23cm depth. One core was filtered using the same 0.45µm cellulose acetate filters as used for the rest of the pore water filtrations conducted on this cruise. The second core was first filtered through an Anachem 0.2µm cellulose acetate syringe filter, while a second aliquot from the same syringe was filtered in-line with the 0.2µm filter with a Whitman Anton 25 0.02µm aluminium oxide filter. All samples were acidified with 25µl of 6M Q-HCl prior to archiving for trace metal analysis.

### 6.2.2 Water column sampling

Water mass distribution in the Montserrat region was characterised by 10 full water column deployments of the CTD (mounted with Sea Bird oxygen and CTG nephelometer/transmissometer sensors) across the study area. Bottom water samples were taken to establish the composition of the water overlying the coring sites. Bottom water oxygen, nutrient and Mn contents are required for interpretation of pore water profiles.

Water samples were collected using a 24x20L Niskin bottle rosette mounted on the CTD system. Rosette positions 1-12 were used solely for trace metal sampling throughout JC18. Rosette positions 13-23 were used for oxygen, nutrient and salinity sampling. Rosette position 24 was used for a IXSEA/VMP transponder. At 8 CTD stations, pairs of 20L Niskin bottles were fired just above sea floor (3-6 m), in the oxygen minimum (~500 m depth) and near surface. At stations 12 and 20, full water column profiles were taken (12 pairs of bottles). The down cast data was used to choose sample depths in regions where water mass characteristics are vertically homogenised over the scale of the water bottles. Water sample numbering was based on CTD firing order.

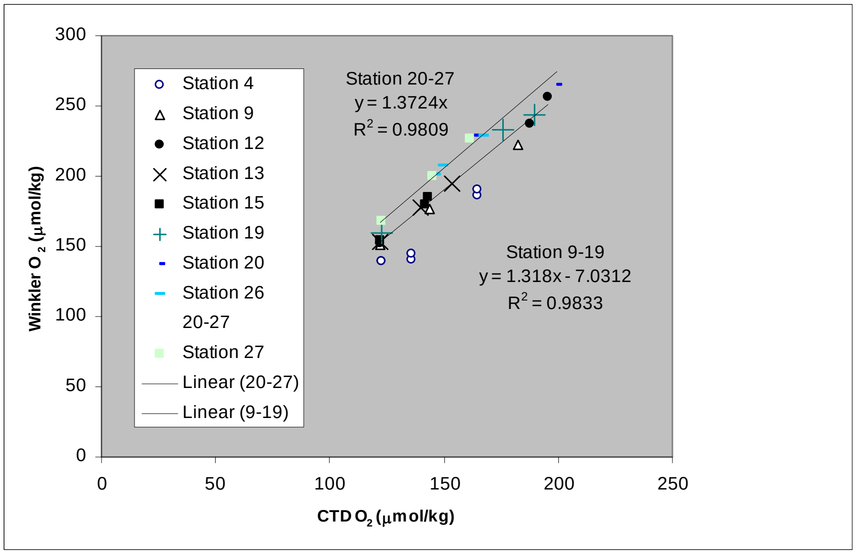
250 ml unfiltered samples were collected for trace metal (Mn) analysis in acid cleaned LDPE bottles. 10 ml sub samples were filtered through a 0.2 μm polycarbonate acid washed filter and collected in acid cleaned 30 ml LDPE bottles. Unfiltered 30 ml samples were collected for nutrient analysis and frozen at -20°C.

The oxygen sensor on the CTD requires accurate calibration to correct the sensor data. This was undertaken by triplicate analysis of 3 water bottles per cast. Oxygen samples were collected for Winkler titration. The thiosulphate standard was calibrated in triplicate at the outset of the JC18 (titre volume: 0.3813 ml). The reagent blank (expressed as titre units) was evaluated (0.00653 ml). Note that oxygen titrations for stations 4 and 5 were compromised by the presence of bubbles in the burette dispenser. The alkaline iodide dispenser broke before fixing of samples from station 20, the data for stations 20-27 used a 1 ml uncalibrated pipette. This meant that a final thiosulphate calibration was not possible at the end of JC18. The Winkler-CTD calibration for stations 9, 12, 13, 15 and 19 was used to correct the CTD sensor data.

A least squares fit through the data for stations 9-19 gives a regression:

$[O_2] = 1.318\ \text{CTD}\ [O_2] - 7.0312 \qquad R^2 = 0.9833$

data in μmol/kg. This regression will be used to correct the CTD oxygen data during post cruise data analysis.




*Winkler derived oxygen content plotted against CTD sensor derived oxygen content for JC018*

CTD data was archived for post cruise processing at NOCS. CTD data were collected from stations 5, 9, 12, 13, 15, 19, 20, 26, 27. The high salinity (~37.25) end member at ~250 m depth is Subtropical Underwater which is derived from evaporation of surface seawater in the eastern Atlantic subtropics. South Atlantic Thermocline waters are present at ~750 m (freshest water at ~6$^{o}$C), this water mass is derived from Antarctic Intermediate Waters. The deepest cold, fresh water is derived from Labrador Sea water.

6.2.3 Pore water extraction

We aim to test the hypothesis that the alteration of recently erupted volcanic ash has a significant impact on marine geochemical budgets. To do this we collect intact surface sediment using a mega corer or a box corer and we extract the interstitial fluids (pore waters) under an inert atmosphere under controlled temperature conditions (~5$^{o}$C). Sediment-water fluxes can be estimated from down core distribution of dissolved constituents. Pore waters were extracted on board and transported to the UK for analysis.

Sediments analysed for pore water extraction involves the sub-sampling of the mega corer and box corer using gravity core liner (6.5 cm i.d.). Pre-cut core liner was inserted into the mega core tube/box core, bunged and extruded and capped for transport to the ship constant temperature laboratory.

The primary method of analysis used on the cruise was the extraction of pore waters by centrifugation. Sub-sampled core is placed in a glove bag kept oxygen free with nitrogen gas (supplemented by wetted Anaerocult™ sachets). The interlock section is flushed with nitrogen so that contamination of the glove bag is minimised. Sub-cores were extruded at 2cm intervals using a plunger. The 2 cm slices were transferred to an 85ml polycarbonate capped bottle and capped within the nitrogen filled glove bag. Consecutive samples were balanced prior to centrifugation at 10,000 rpm for 10-20 minutes.

Supernatent water is siphoned from the sediment surface in the glove bag with a 20 ml syringe. The fluid is then filtered through a 0.45 μm PTFE 25 mm filter. The first 1 ml of filtrate was discarded. 5ml samples were collected (volume permitting) for nutrient analysis in 8 ml acid cleaned HDPE Nalgene bottles (frozen at -20$^{o}$C). The remaining sample was collected for trace metal/isotope analysis in acid cleaned LDPE Nalgene bottles (acidified with ~50 μl sub boiling distilled 6M HCl per 10 ml pore fluid).

An alternative method of pore water extraction is using Rhizon™ samplers. Gravity core liner (6.5 cm i.d.) was pre-prepared with 3 mm diameter holes drilled at 1 cm intervals. These are covered with electrical tape for sub-sampling of box and multi cores. After sub-sampling, the core is placed in a cradle and Rhizon samplers inserted at appropriate intervals. Initial extractions were conducted horizontally which compromised vertical structure because the viscous volcanic upper layers slump within the core liner. Subsequent extractions were carried out with the subcore aligned vertically. Sampled pore waters were sub-sampled for nutrient and trace metal/isotope analysis as above.

At station 33 a comparison of 0.45 μm PTFE filtration with 0.2/0.02 μm filtration was carried out by collecting duplicate sub-cores (10 cm i.d.) from a box corer deployment. This will allow assessment of the colloidal pore water content within the volcanogenic sequences at this site.

Pore water samples were numbered consecutively in order of sample acquisition throughout JC18. Samples for each core were bagged and labelled with station number using standard protocols. Samples will be analysed for nutrients, trace metals and isotopes at NOCS and Portsmouth.

6.2.4 Faunal studies

Research focuses on Foraminiferida, Pteropoda (holoplanktonic gastropods), Ostracoda and otoliths (stato-acoustic organs of teleost fish) found in marine sediments in the vicinity of Montserrat (Lesser Antilles volcanic arc). Using faunal data and analysis of stable isotopes, the chronology of ash-fall and other volcaniclastic deposits are being investigated. The microfaunas are abundant and well-preserved and provide information on both stratigraphy and the climatic history of the Eastern Caribbean Sea.

Some samples collected during JC18 have been processed on board ship while others will have to be collected from cores on return to the UK. Further AMS dates will be required as the limited carbonate sediment present between the deposits often provides limited scope for an unequivocal stable isotope stratigraphy. Each AMS date requires ~1000 hand-picked mono-specific samples of foraminifera and is time-consuming work. Dating the events is complicated by the removal of hemi-pelagic sediment below the erosive surfaces that often characterize these deposits.

Samples collected during the cruise have been washed, fixed in buffered formalin and then stained with Rose Bengal on board. This was a complicated and time-consuming process, but should identify the foraminifera that were living (stained) at the time of collection as distinct from the dead or transported fauna (not stained). Knowledge of the eruption history of the volcano means that we have accurate timings for the sea floor volcaniclastic sediments and we can – therefore – time recovery accurately. The anticipated recovery of the fauna on the surface of the 2003 deposits has been complicated by the arrival of the 2006 sediments. This means that the post-2003 fauna (if there was one in situ) will have been ‘killed’ and we can only sample the top of the 2003 deposits in the hope of seeing a “recovery” fauna. After the May 2006 eruption it is unlikely that any of this fauna will take up a stain. To our knowledge this is the first time that such work has been attempted (especially at sea) and the samples returning to the UK will require some careful analysis.

In the area to the west of Montserrat a number of core-topes with a thin ash layer also have a topmost 1 cm characterized by very abundant pteropods that appear to have been removed from the plankton by the ash-fall. The mechanism to explain such a phenomenon is not known.

As our micropalaeontological research requires many hours of microscope work (both optical and SEM) no results can be generated at sea (with the facilities on the RRS *James Cook*). Work on board has concentrated on collection. Processing, staining and curating suites of samples from each site for subsequent research.

Other avenues of research may be identified as the samples are studied. In particular we have some interesting data on the succession of carbonates sitting atop the two ‘extinct’ volcanic centres to the SE of Montserrat. We are hoping to study this succession including a ‘hardground’ present 20 cm below the sediment surface. JC18-32 also recorded this serpulid-rich hardground at the bottom of the mega-core, approximately 15 cm below the top of the hemipelagic sediments. This would indicate that this hardground is present both inside the old crater and on the col between the two centres. More surprisingly at this location was the presence of a considerable thickness of ash and the mechanism for its sedimentation in this very positive area is not known, especially as other volcaniclastic sediments have previously been limited to more basinal areas. In particular we are interested in how benthic foraminifera have re-colonized the crater which lies well above the surrounding sea floor. There is a suggestion that colonizing such virgin areas may be by a yet unproven “propagule” method (as suggested by Elizabeth Alve and Susan Goldstein). This clearly needs investigation using both these elevated sites and other areas smothered in soft ash/mud.

6.2.5 Microelectrode and gel probe studies

Oxygen and redox gradients were measured on collected mega-core tubes using Unisense microelectrodes. The reason for using this in-situ technique is that during extrusion and centrifugation artefacts can be induced such as intrusion of oxygen. Previous use of the oxygen microelectrodes during JCR123 showed oxygen depletion in the surface 5-15 mm depending on the thickness of the ash layer. Also large volumes are needed for oxygen titrations. The use of this in-situ technique enables oxygen and Eh pore water gradients to be measured on a vertical resolution of 100 microns.

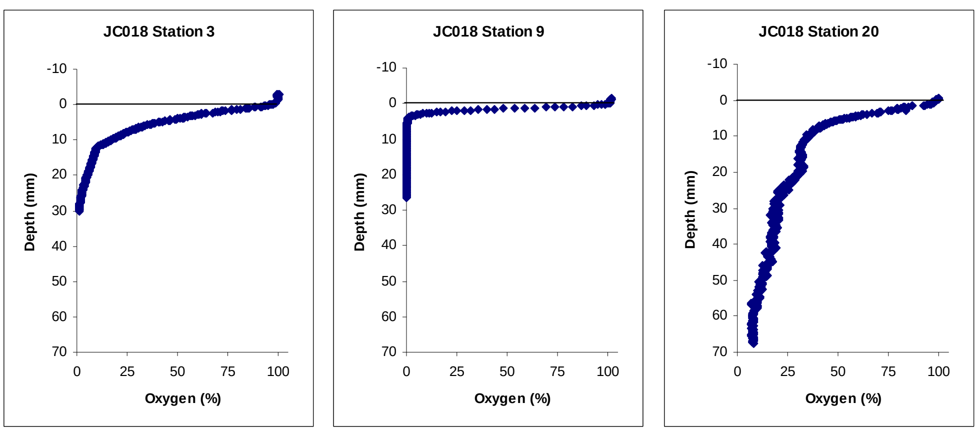
Due to the nature of the sediments and the fine scale high resolution gradients anticipated for the other solutes inferred from the preliminary $O_2$ profiles, conventional pore water techniques may miss some of the important features in the top 1-2cm of the ash layer. The technique of Diffusive Equilibration in Thin films (DET) has been successively used in marine sediments to measure major ion and Fe and Mn concentrations at high resolution (~1-2mm). However, the DET technique does not capture sufficient pore water to allow measurement of critical species that are present at low concentrations or require larger sample volumes (e.g., transition metals). Therefore the technique of Diffusive Gradients in Thin-Films (DGT) has also been used during this cruise. DGT uses a Chelex 100 resin to pre-concentrate transition elements to enable low levels in the pore waters to be determined. DGT is a perturbation experiment and thus does not give overall concentrations but does identify sources and sinks of trace metals on the mm scale. DGT has been successfully deployed in the North Atlantic, Black Sea, North Sea and fresh water rivers in France.

Sediment with the ash layers intact were collected using either a box-corer or a mega-corer (10cm diameter). Upon retrieval of the mega-core a sub sample core was pushed down through the sediment and the sub-core extruded. This was then placed in the constant temperature lab at a temperature of 6°C. Oxygen and redox profiles were performed on the sub-core using a Unisense microelectrode system with 50 μm oxygen and redox microelectrodes, this enabled a vertical resolution of 100 μm to be achieved.

The electrodes underwent a 2 point calibration and were stepped down at 100 μm intervals using the Unisense stepper motor. Some analyses were also undertaken on sub-cores collected from a number of box cores.

The previously made DET and DGT probes were de-oxygenated in a chelex 100 cleaned artificial sea water matrix (0.4 M NaCl) for a period of 24 hours. Collected mega-core tubes were placed in the racks in the CT lab and the gel probes were pushed in carefully up to the pre-determined sediment-water interface mark. Gel probes were left then to equilibrate (DET) or accumulate (DGT) with the surrounding pore waters for periods of 24-29 hours. Upon retrieval the probes were wiped clean of any sediment and a plastic cover slip placed over the face. The probes were then bagged and placed in a plastic storage box for transport back to Portsmouth. 18 DET and DGT probes were collected from a range of sites during the cruise. These will be post-processed and analysed at University of Portsmouth.

Oxygen pore water profiles were obtained at 26 sites, some of which are illustrated in the figure below. No results for redox probes are given as these need be assessed after the cruise. This figure also highlights the difference in oxygen penetration seen during the cruise at the different sites, ranging from 4 mm to > 6 cm.




*Oxygen pore water profiles from 3 contrasting sites.*

The gel probes will be analysed using ICP-MS. For the DET gel probes the individual pieces of gel will be removed and back eluted with 500 μL of 1M nitric acid. This will enable the analysis of Fe and Mn concentrations and other analytes to be determined in the sediment pore waters. Depth profiles will then be constructed as the first part of the data interpretation. The DGT probes will be sliced at 1 mm resolution at the surface and coarser resolution down core, and then the trace metals extracted using 2M nitric acid. The eluent will be further diluted and analysed using ICP-MS for transition metals. This will give a first indication of sources and sinks on a mm scale within the ash layers and underlying sediment.

Oxygen and redox profiles will be re-processed at NOC to convert % saturation to oxygen concentration (μmol $O_2$/l). These will then be re-adjusted to take into account the bottom water concentrations observed from the CTD profiles.

Unfortunately the redox microelectrodes proved problematic. Unisense guidelines were followed for calibration and the first few profiles seemed erratic. Microelectrodes had to be cleaned in nitric acid after each use. The reference electrode end got discoloured and this may have led to the redox probes becoming unstable. A 160+ mV difference was achieved with the two point calibration, but when the new electrode was used the difference was an order of magnitude less. The oxygen microelectrodes worked well, with both being used after the redox probe was no longer working. They calibrated well and produced a large data set. The gel probes also seemed to have some problems with the interface being hard to distinguish and some sediment leaking in around the back of the probe, these will have to be assessed when the probes are dismantled. The interface problem was overcome by marking a boundary on the probes and pushing the probes into the pre-determined sediment-water interface. The use of mega-cores and box cores also provided some additional problems. The mega cores had to be extruded and this ultimately led to disturbance of the sediment water interface, the box cores didn't suffer from the same problem but these had been disturbed before the sub cores had been extracted. Both sampling techniques had their limitations but ultimately a large data set of oxygen profiles was obtained.

6.2.6 Molecular-level geochemical analyses of Fe (and Mn)

Aqueous ferrous iron is an extremely important reductant in a wide variety of natural anoxic environments including marine sediments. Organic carbon levels in the Montserrat tephra are <0.05 wt.% and $O_2$ depletion likely arises from oxidation of Fe(II) released during diagenesis of the tephra. However, as is now recognised for the vast majority of cations, the fate and mobility of Fe(II) (and Mn(II)) in natural environments is controlled by its sorption to natural mineral and organic particles. Both FeMn (hydr)oxides and phyllosilicate clay minerals strongly sorb trace-metal species from aqueous solution, via isomorphous substitution of structural cations (solid solution), formation of inner-sphere (specific adsorption) or outer-sphere (cation exchange) surface complexes, or formation of surface precipitates. Sorption reactions at the various mineral-water interfaces present in the tephra and mixed tephra-pelagic sediment layers are likely an important control on the fate and mobility of redox-labile reduced Fe (and Mn) in diagenetic tephra sediments. Accordingly, molecular-level geochemical analyses of Fe oxidation state and crystal chemistry are key to fully determining the controls on the redox state of the diagenetic sediment column and thus the controls on the redox cycling of biolimiting trace-species in ash-bearing sediments.

Box cores (7, 8, 9, 12) and mega cores (5, 10) were subsampled immediately after recovery using modified 50ml disposable plastic syringes. Syringes were plunged into the exposed sediment face and drawn until full; open syringe ends were parafilmed to minimise oxygen contamination. Sealed syringes were immediately transferred to a $N_2$ flushed glove bag and partially extruded (~3cm) to remove potentially oxygen contaminated sediment. Open syringe ends were resealed with parafilm and sealed inside aluminium bags. Samples were removed from the glove bag and stored at $6^oC$.

Box cores (14) and mega cores (17, 19, 22, 25, 26, 27, 29) were subsampled in conjunction with pore water extraction inside a $N_2$ flushed glove bag. Small sediment sub-samples were removed from each pore-water subsection and sealed inside disposable plastic press-lock bags that were sealed inside aluminium bags, removed from the glove bag and stored at 6$^{o}$C.

Three days beam time at Synchrotron Research Source (SRS) Daresbury have recently been awarded to investigate Fe and Mn oxidation state and associated crystal chemistry in key sediment samples recovered during JC18. Sample mineralogy, trace-element associations, Fe and Mn oxidation state and Fe/Mn crystal chemistry will be investigated with XRD, XRF, XANES (x-ray absorption near edge spectroscopy) and EXAFS (extended x-ray absorption fine structure spectroscopy), respectively. Sample stations at SRS are designed for redox sensitive samples, and, as such, *in situ* redox conditions will be maintained throughout the analyses. Molecular-level results will be combined with trace-element and dissolved $O_2$ pore-water analyses to determine the controls on the redox state of the ash-bearing sediments surrounding Montserrat.

6.2.7 Physical Sediment Studies

Three different coring techniques were used: gravity cores, mega cores and box cores. The gravity cores seldom recovered more than 20-50 cm of sediment, regardless of the length of the core barrel (1-6 m), the size of the weights (0.45-1.6 t) and the run in speed (40-100 m/min). We occupied one site (19) at which a French cruise had recovered a ~5 m piston core, but we only managed to recover 30-45 cm of sediment in two gravity core attempts. There were no obviously resistant layers in the French core, so the reasons for the ineffectiveness of the gravity core are uncertain.

The mega core was often more successful than the box core in penetrating hemipelagic mud rich in bioclasts. This suggests that slower penetration of the sandy sediment produces better recovery than the faster and heavier box core.

The cores were described visually and logged at a scale of 1:5.

The gravity cores were split using the NOCS core splitter, but it was almost impossible to recover any of the soupy ash in this way. Box cores and mega cores were sub-sampled with a section of gravity core liner and sealed with bungs at either end. Description of these cores was based on visual observations through the core wall and observation of successive samples extruded for faunal analysis. These archive cores were prepared for intact transport back to the UK, where they can be split and sampled under controlled conditions.

The cores collected during JC18 will add to the extensive suit of cores recovered during JCR123 in the same waters, and will arguably produce the most detailed submarine record available for an island arc volcano. This will allow us to document in detail the sedimentological and volcanological characteristics of the May 2006 Soufriere Hills dome collapse deposits. This collapse deposited ~190 million cubic metres into the ocean as a continuous flow (with two main pulses of activity) in just 45 minutes. For comparison, the previous dome collapse in 2003, involving similar volumes of material, collapsed into the sea as numerous small scale events over >12 hours. Study of the geometry of the deposits, using swath bathymetry and sub-bottom seafloor profiles, will show us how the material was disseminated as it entered the sea, and core samples will provide grain size trends and components.

Together with the subaerially sourced pyroclastic units, the marine sedimentary deposits contain evidence of periodic submarine slope failure that produced landslides. Such deposits are observed intercalated with the volcanic deposits in the core samples. Landslides into the ocean and submarine landslides have the potential to form tsunamis. It is important to understand the dynamic flow processes behind these natural hazards, as determined by the study on the resulting deposits. For example, if a collapse occurs over a period of time as numerous small scale failures, the tsunami threat is far less than the entire mass failing in one go. The Montserrat cores provide much needed data for further study into these phenomena.

### 6.2.7 Microbiological Studies

The objectives of the microbiological studies were; to examine anaerobic ammonium oxidizing (anammox) bacteria and denitrifying bacteria in the sediments, to examine microbial community structures within the top 5 cm of sediments from each sampling site, and to determine microbial stratification along redox gradients.

A sample of the top 5 cm of sediment was collected from either mega cores or box cores with two 50 ml Falcon tubes for incubation experiments, and two 15 ml tubes for DNA extraction. Additional sediment samples (from the top 3 cm) were collected in 20 cc syringes from the core samples after either oxygen probe or gel probe analyses. The sediments collected in the 50 ml Falcon tubes were stored in the 4°C fridge, and the samples collected in the 15 ml tubes and syringes were stored in -80°C freezer.

$^{15}N$ stable isotope incubation experiments were conducted during the cruise to measure anammox and denitrification activities in the sediments. Approximately, 1 g of wet sediments were transferred to Exetainer tube (12 ml) and flushed with He gas for 5 min. The tubes were sealed with gas tight caps and flushed again with He gas for 5 min. The tubes were stored at room temperature overnight to consume the residual $NH_4^+$, $NO_3^-$, $NO_2^-$ in the sediments. After overnight incubation, the tubes were flushed again with He gas. Two different combinations of N-substrates ($^{15}NH_4^+$ and $^{14}NH_4^+$+$^{15}NO_3^-$) were spiked in final concentration of 50 μM-N. The incubation was stopped at 0, 6, 12 and 24 hr by adding 73% $ZnCl_2$ (0.1 ml). The tubes were stored at room temperature for later isotope GCMS analysis at UNCW. After bringing the tubes back to UNCW, $^{29}N_2$ and $^{30}N_2$ gas productions were measured to detect anammox and denitrification. The tubes with the station 12 sediments were initially analyzed and found to have both $^{29}N_2$ and $^{30}N_2$ in the samples amended with $^{14}NH_4^+$+$^{15}NO_3^-$. This demonstrated the presence of anammox and denitrifying bacteria in this sediment. Further analysis will be conducted with other sediment samples and the rate of both bacterial activities will be calculated.

Anammox bacterial communities in the sediment samples were examined with the DNA extracted from 8 stations (12, 13, 14, 15, 17, 18, 19 and 20). Anammox specific PCR was used to detect anammox bacteria. PCR amplified the expected size fragments from the DNA extracted from stations 12, 14, 15, 16 and 17. Cloning and sequence analysis of the amplified products will be conducted to identify anammox bacteria and to determine the diversity of the bacteria.

Bacterial communities were examined by targeting 16S rRNA genes using PCR amplification with universal primers. T-RFLP analysis of 16S rRNA genes was initially conducted to obtain a snapshot of community structures in 8 sites where DNA was extracted. PAT-TRFLP analysis was conducted to identify major bacterial populations based on T-RFLP patterns and NCBI database analysis. Cloning and sequence analysis of 16S rRNA genes are underway to examine diversity of microbial communities in each station.

**SAMPLE CATALOGUE**

| **Station & Activity** | **Samples** |
|---|---|
| JC18-1-BX | Microbiology<br>Sediment archive |
| JC18-2-MC | Microbiology<br>Faunal analysis |
| JC18-3-MC | Microbiology<br>Gel probes<br>Microelectrode analysis<br>Faunal analysis<br>Pore water extraction |
| JC18-4-GC6 | Sediment log and archive |
| JC18-4-MC | Sediment log and archive<br>Faunal analysis<br>Microbiology<br>Rhizon pore water analysis<br>Micro electrode study |
| JC18-4-CTD | Water samples |
| JC18-5-CTD | Water samples |
| JC18-5-MC | Fe oxidation state<br>Microbiology |
| JC18-7-MC | Microbiology<br>Faunal analysis |
| JC18-7-BX | Sediment log and archive<br>Rhizon pore water analysis<br>Faunal analysis |
| JC18-8-MC | Rhizon pore water analysis<br>Gel probes<br>Sediment log and archive |
| JC18-8-BX | Sediment log and archive<br>Faunal analysis<br>Microbiology<br>Micro electrode study<br>Pore water extraction |
| JC18-9-MC | Rhizon pore water analysis<br>Gel probes<br>Faunal analysis |
| JC18-9-BX | Fe incubation experiments<br>Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Fe oxidation state<br>Microbiology |

| | |
|---|---|
| JC18-9-CTD | Water samples |
| JC18-10-MC | Micro electrode study<br>Faunal analysis<br>Microbiology<br>Sediment log and archive<br>Rhizon pore water analysis |
| JC18-11-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes |
| JC18-11-GC6 | Sediment log and archive |
| JC18-12-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes<br>Microbiology<br>Pore water extraction |
| JC18-12-GC6 | Sediment log and archive |
| JC18-12-CTD | Water samples |
| JC18-12-BX | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes<br>Pore water extraction<br>Rhizon pore water analysis |
| JC18-13-MC | Micro electrode study<br>Faunal analysis<br>Microbiology<br>Sediment log and archive<br>Gel probes<br>Pore water extraction |
| JC18-13-CTD | Water samples |
| JC18-13-GC6 | Sediment log and archive |
| JC18-13-BX | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Pore water extraction<br>Rhizon pore water analysis |
| JC18-14-GC6 | Sediment log and archive |
| JC18-14-MC | Micro electrode study<br>Faunal analysis<br>Microbiology<br>Sediment log and archive<br>Gel probes<br>Pore water extraction |

| | |
|---|---|
| JC18-15-GC6 | Sediment log and archive |
| JC18-15-MC | Micro electrode study<br>Faunal analysis<br>Microbiology<br>Sediment log and archive<br>Gel probes<br>Pore water extraction |
| JC18-15-CTD | Water samples |
| JC18-17-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes<br>Pore water extraction<br>Microbiology |
| JC18-18-MC | Faunal analysis<br>Sediment log and archive<br>Gel probes<br>Pore water extraction |
| JC18-18-BX | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Fe incubation experiment<br>Microbiology |
| JC18-19-GC3 | Sediment log and archive |
| JC18-19-MC | Micro electrode study<br>Faunal analysis<br>Microbiology<br>Sediment log and archive<br>Pore water extraction |
| JC18-19-CTD | Water samples |
| JC18-19-GC6 | Sediment log and archive |
| JC18-20-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes<br>Microbiology |
| JC18-20-CTD | Water samples |
| JC18-21-GC3 | Sediment log and archive |
| JC18-21-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes |
| JC18-22-GC6 | Sediment log and archive |
| JC18-22-MC | Micro electrode study<br>Faunal analysis |

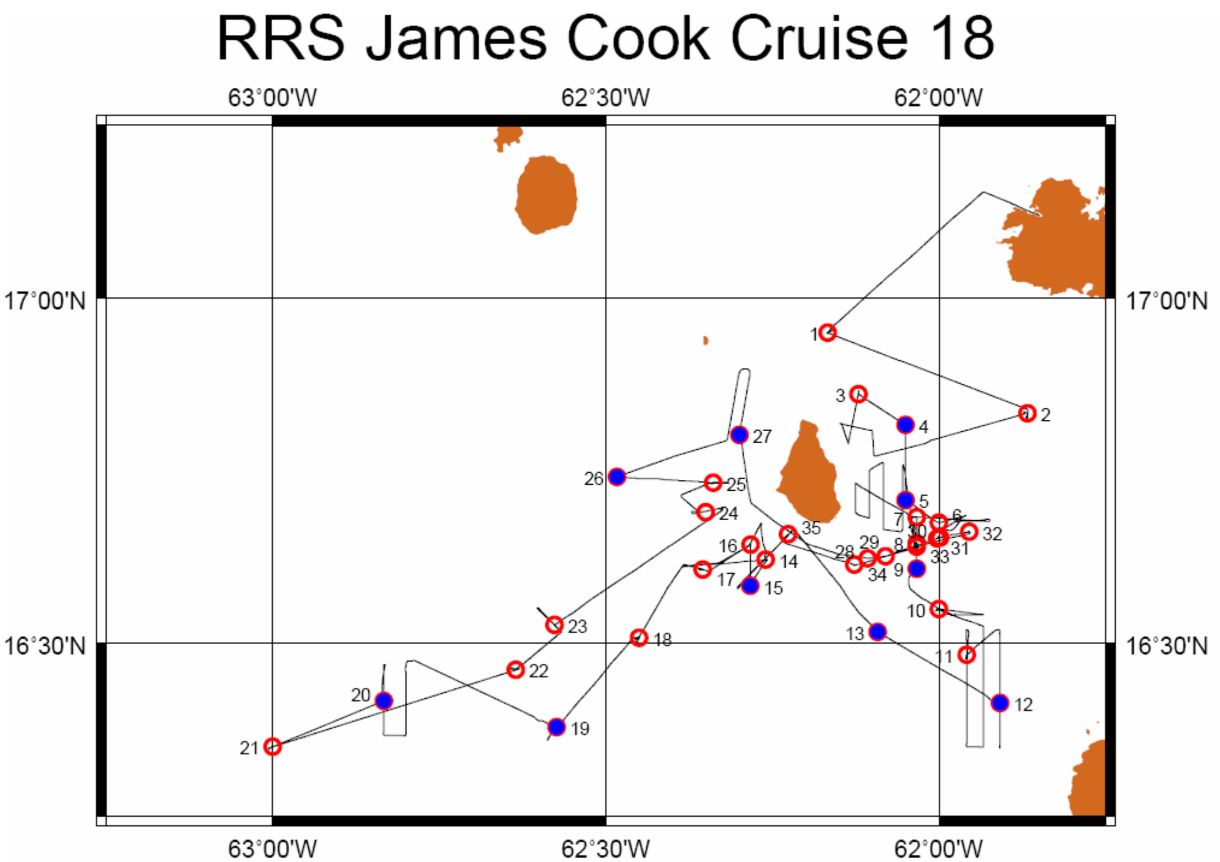
| | |
|---|---|
| | Sediment log and archive<br>Gel probes<br>Pore water extraction |
| JC18-22-GC3 | Sediment log and archive |
| JC18-23-GC3 | Sediment log and archive |
| JC18-23-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes |
| JC18-24-GC3 | Sediment log and archive |
| JC18-24-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes<br>Pore water extraction |
| JC18-25-GC3 | Sediment log and archive |
| JC18-25-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes |
| JC18-26-GC3 | Sediment log and archive |
| JC18-26-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Gel probes |
| JC18-26-CTD | Water samples |
| JC18-27-GC3 | Sediment log and archive |
| JC18-27-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive<br>Fe oxidation state study<br>Rhizon pore water analysis |
| JC18-27-CTD | Water samples |
| JC18-28-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive |
| JC18-29-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive |
| JC18-32-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive |
| JC18-33-BX | Micro electrode study<br>Faunal analysis<br>Sediment log and archive |

| | |
|---|---|
| | Fe oxidation state study<br>Pore water extraction<br>Rhizon pore water analysis |
| JC18-34-MC | Micro electrode study<br>Faunal analysis<br>Sediment log and archive |
| JC18-35-MC | Sediment log and archive |

## 7. STATION LIST

| Station | Latitude | Longitude | Water Depth |
|---|---|---|---|
| JC18-1 | 16$^{o}$57.00’N | 62$^{o}$10.00’W | 710 m |
| JC18-2 | 16$^{o}$50.00’N | 61$^{o}$52.00’W | 700 m |
| JC18-3 | 16$^{o}$51.66’N | 62$^{o}$07.25’W | 725 m |
| JC18-4 | 16$^{o}$49.00’N | 62$^{o}$03.00’W | 820 m |
| JC18-5 | 16$^{o}$43.00’N | 62$^{o}$03.00’W | 1025 m |
| JC18-6 | 16$^{o}$40.50’N | 62$^{o}$00.00’W | 1088 m |
| JC18-7 | 16$^{o}$41.00’N | 62$^{o}$02.00’W | 1080 m |
| JC18-8 | 16$^{o}$38.70’N | 62$^{o}$02.00’W | 1110 m |
| JC18-9 | 16$^{o}$36.50’N | 62$^{o}$02.00’W | 1133 m |
| JC18-10 | 16$^{o}$33.00’N | 62$^{o}$00.00’W | 1167 m |
| JC18-11 | 16$^{o}$29.00’N | 61$^{o}$57.50’W | 1203 m |
| JC18-12 | 16$^{o}$24.80’N | 61$^{o}$54.50’W | 1217 m |
| JC18-13 | 16$^{o}$31.00’N | 62$^{o}$05.50’W | 984 m |
| JC18-14 | 16$^{o}$37.30’N | 62$^{o}$15.60’W | 805 m |
| JC18-15 | 16$^{o}$35.00’N | 62$^{o}$17.00’W | 908 m |
| JC18-16 | 16$^{o}$38.61’N | 62$^{o}$16.97’W | 706 m |
| JC18-17 | 16$^{o}$36.44’N | 62$^{o}$21.26’W | 804 m |
| JC18-18 | 16$^{o}$30.50’N | 62$^{o}$27.00’W | 787 m |
| JC18-19 | 16$^{o}$22.70’N | 62$^{o}$34.41’W | 1130 m |
| JC18-20 | 16$^{o}$25.00’N | 62$^{o}$50.00’W | 1933 m |
| JC18-21 | 16$^{o}$21.00’N | 63$^{o}$00.00’W | 1270 m |
| JC18-22 | 16$^{o}$27.70’N | 62$^{o}$38.08’W | 1100 m |
| JC18-23 | 16$^{o}$31.60’N | 62$^{o}$34.60’W | 959 m |
| JC18-24 | 16$^{o}$41.70’N | 62$^{o}$20.00’W | 995 m |
| JC18-25 | 16$^{o}$44.00’N | 62$^{o}$20.31’W | 878 m |
| JC18-26 | 16$^{o}$44.50’N | 62$^{o}$29.00’W | 1069 m |
| JC18-27 | 16$^{o}$49.50’N | 62$^{o}$18.00’W | 926 m |
| JC18-28 | 16$^{o}$37.40’N | 62$^{o}$06.42’W | 1023 m |
| JC18-29 | 16$^{o}$37.60’N | 62$^{o}$04.80’W | 1070 m |
| JC18-30 | 16$^{o}$39.20’N | 61$^{o}$59.89’W | 1105 m |
| JC18-31 | 16$^{o}$39.20’N | 62$^{o}$00.17’W | 1103 m |
| JC18-32 | 16$^{o}$39.70’N | 61$^{o}$57.20’W | 876 m |
| JC18-33 | 16$^{o}$38.40’N | 62$^{o}$02.00’W | 1114 m |
| JC18-34 | 16$^{o}$36.85’N | 62$^{o}$07.60’W | 986 m |
| JC18-35 | 16$^{o}$39.49’N | 62$^{o}$13.59’W | 660 m |

## 8. CHARTS




*Cruise track of JC18 with Site locations numbered.*

## 10. RECOMMENDATIONS

1. The start and finish of the cruise both took place on Sunday in Antigua. Services in Antigua are not highly efficient at the best of times, and life pretty much grinds to a halt on a Sunday. This made it difficult to access vital services at both ends of the cruise and resulted in departure delays for both JC23 and JC24. Despite the fact that both cruises were relatively short in duration (13 days and 6 days, respectively), we were fortunate that neither of these delays significantly impacted the scientific activities. Nevertheless, it might be useful to schedule departure and arrivals for week days in Antigua for any future cruises to avoid (or at least minimise) this problem. This would have been relatively simple to arrange in this instance as JC23 was preceded by a long transit leg and five days in port and JC24 was followed by several days in port and another long transit leg.

2. In the past I have used the sub-bottom profiler on the RRS Charles Darwin to help distinguish areas of hard and soft bottom when choosing core sites. However, for the system deployed on the RRS James Cook this distinction was not apparent to me, or anyone else, onboard. Some consideration should be given to training NERC operational staff into interpretation of the sub-bottom profiler signal.

3. Some thought needs to be given into improving the recovery procedure for longer gravity (and piston) cores. In the mean time it may be worth placing some sacrifice material (e.g., some matting) over the starboard side where the core is recovered.

4. We came to rely almost exclusively on the mega corer. However, it has to be acknowledged that they are more susceptible to damage during heavy use in rough seas. Hence, we recommend that the purchase of an additional mega corer from the marine equipment budget.