DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2007/44

GALATHEA3 - LEG 16 WINMARGIN Project

West Indies Marine Geoscience Investigations

A. Kuijpers & Project Group

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

GEUS

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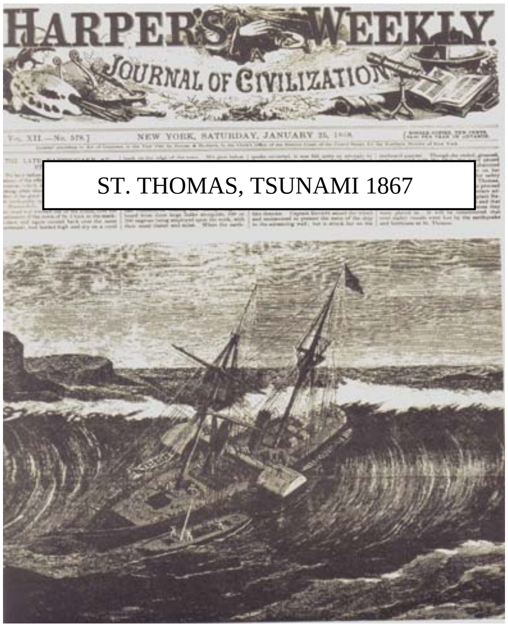
G E U S

GALATHEA3 – LEG 16

WEST INDIES MARINE GEOSCIENCE INVESTIGATIONS

‘ WINMARGIN ’

Plate tectonics and Earthquakes, Hurricanes, and Ocean Circulation Changes



Watlington and Lincoln, 1997

Cruise & Field Report

HDMS ‘Vædderen’

H.L. Andersen, J. O. Leth, P. Knutz, M.-S. Seidenkrantz, N. Grindlay, H. Kunzendorf
&
Shipboard Party

———

RV ‘Bright Star’

A. Kuijpers, J. B. Jensen, R. Endler, G. Nickel

———

Land Team St. Croix

J. Bartholdy, J. B. Torp Pedersen

Summary – Project Objectives and Acknowledgements

A. Kuijpers & Project Group

The 'WINMARGIN' project idea was developed in 2005 as a continuation of previously (1994) started climate-related projects in the Northeast Caribbean carried out by GEUS in collaboration with Göteborg University (B. A. Malmgren) and funded by the Swedish Research Council and EU 'PACLIVA' project. The Galathea3 proposal originally titled *'Marine Geoscience Investigations of the former Danish West Indies'* has been based on collaboration of three Danish institutions, i.e. GEUS (A. Kuijpers), the University of Copenhagen (J. Bartholdy, C. Christiansen, H. Kunzendorf, P. Knutz) and the University of Aarhus (H. L. Andersen, M.-S. Seidenkrantz).
Involvement of the University of the Virgin Islands (UVI), St. Thomas, in above projects started in 2003 during the 'PACLIVA' project and was formalized by a Memorandum of Understanding signed between UVI and the University of Copenhagen in 2004.

The main objectives of the 'WINMARGIN' project are:

* to improve our knowledge of regional plate tectonic setting and sediment stability (tsunami risk)

** to trace possible links between oceanographic changes and North Atlantic climate (e.g. hurricane) variability with the ultimate aim of better understanding possible influences of the tropical Atlantic on high-latitude climate

The WINMARGIN contribution to the Galathea3 Expedition was three-fold, i.e. two different operations at sea and one land-based field campaign. As the work described in the original proposal was based on 19 days of ship-time, and granted ship-time was 8 days, a 2-ship survey plan was developed. For the sea-going activities the main operation onboard HDMS '*Vædderen*' included acquisition of multi-channel (sleevegun) seismic data, multi-beam echo-sounder profiling, sediment sampling using a gravity- and box corer system and hydrographic (CTD) data collection. This work was carried out in the period 18-26 March 2007 (St. Thomas – St. Croix). A more detailed cruise report is presented in the following chapter by H. L. Andersen et al. In addition, through collaboration with UVI a smaller research vessel (*' Bright Star'*) was chartered for carrying out the originally planned shallow seismic survey in coastal-near areas. The latter survey (see Kuijpers et al., this report) was carried out between 14 March and 23 March 2007, with *'Bright Star'* docking at facilities of UVI's Center for Marine and Environmental Studies, St. Thomas, during the beginning and final phase of the work. In the intervening period the vessel docked at UVI's 'VIERS' station on the south coast of St. John. Within the framework of many years of collaborative projects, the Baltic Sea Research Institute ('IOW') in Warnemünde, Germany, participated here and contributed with acoustic equipment of the latest-state-of-the art. As for the investigations onshore, the island of St. Croix was selected as being most promising for providing suitable (onshore) coring sites for studying hurricane- and tsunami-related coastal deposits. The onshore fieldwork carried out on St. Croix is described by J. Bartholdy in the last chapter of this report.

The WINMARGIN project would not have been possible without funding by the *'Villum Kann Rasmussen'* Foundation (www.velux.com), with additional support received from GEUS, the University of Copenhagen and the University of Aarhus. Thanks are also due to the Galathea3 organisation committee for their efforts and initiative. We sincerely acknowledge this funding and support. Furthermore, we thank UVI , and in particular Prof. R. Watlington, for support at numerous occasions, making university facilities available and help with formal and logistic issues. The commanding officer of HDMS '*Vædderen*' and captain of RV '*Bright Star'*, R. Vante, with respective crews are thanked for their engagement and support during the work at sea. For the '*Bright Star'* survey, we highly appreciate the assistance by UVI's Center for Marine and Environmental Studies, and we would like to mention in particular K. Brown, who helped with technical questions. Last but not least, thanks are due to the technical staff of GEUS (J. Boserup, E. Hansen), the University of Aarhus (P. Trinhammer) and the Danish Institute for Fisheries Research (T. Nielsen, J. Friis-Christensen) for their efforts in helping to make the operations successful. This also applies to P. Larsen and H. Holm (Royal Danish Administration of Navigation and Hydrography) for their contribution with the acquisition of multi-beam bathymetric data.

1. Galathea-3 Leg 16 Virgin Islands Basin

WINMARGIN-project

H.L. Andersen, J.O. Leth, P. Knutz, M.-S. Seidenkrantz, N. Grindlay, H. Kunzendorf
&
Shipboard Party

A - Reflection seismic activities

Seismic crew

Per Trinhammer, University of Aarhus
Sara Raussen, University of Aarhus
Katrine Andresen, University of Aarhus
Egon Hansen, Geological Survey of Denmark and Greenland
Kristina Ravnsgaard Nielsen, University of Copenhagen
Nancy Grindlay, University of North Carolina Wilmington
Holger Lykke-Andersen, University of Aarhus

Cruise plan

The cruise plan laid out in the original document describing the seismic activities in the Winmargin-project is shown in Fig. 1.

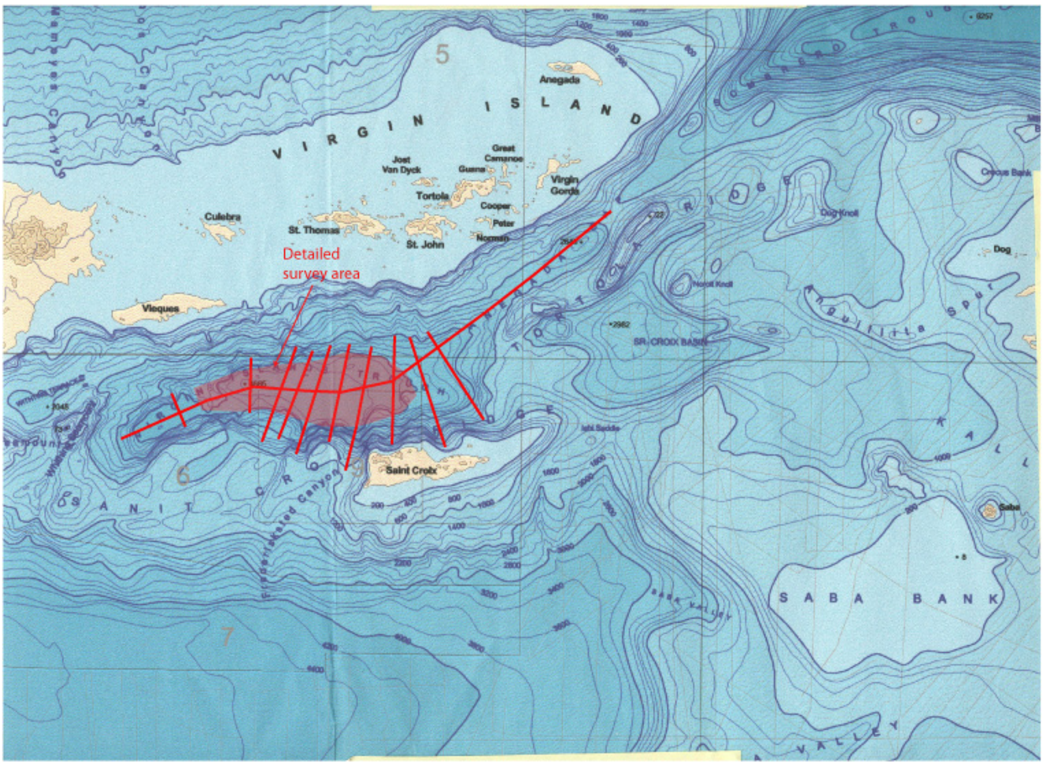


Fig. 1 Cruise plan designed August 2005

Instrumentation

The seismic instruments were installed in container 5 (rear container on starboard side of the aft deck) on March 18.2007. The seismic data was acquired with reflection seismic instruments provided by University of Aarhus.

Seismic source
GI gun 45/105 cubic inch. Firing pressure 120 bar
Firing control system Macha TGS-8

Streamer
Hydrosciences analogue streamer. 96 hydrophone groups, group separation 6.25 m, active length 594 m, with 5 Digicourse birds used as depth controllers.

Recording equipment
2 Geometrics Strataview R48 (96 channels)
Geometrics acquisition control unit CNT-1
Recording media: hard disk and LTO-tape

Navigation
Javad GPS-receiver with the Eiva NaviPac software used for navigation

Acquisition parameters
Cruising speed: ca. 5 Kn
Shot interval: 25 m controlled by navigation system
Sample interval: 1 msec
Recording length: 8 sec
Acquisition filters:
Low cut 10 Hz 24 dB/Oct
Anti alias filter: 300 Hz
Recording format: SEGD ver 8058
Coordinates: WGS-84, UTM Zone 20
Time reference: UTC
Near offset: 30 m

Test of ships noise

Prior to the acquisition of seismic profiles a test of the propeller noise was performed. The noise emitted by the propeller was taken up by a hydrophone mounted in the ships hull immediately above the propeller. The frequency spectrum of the noise was displayed on an oscilloscope. A series of experiments were carried out keeping the ships speed at 5 knots and varying rotational speed of the propeller and the pitch of the propeller blades. It was found that the low frequency part of the noise i.e. 10-80 Hz was at a minimum at 92 RPM and pitch 3 (arbitrary units). Furthermore, it was found that the noise was additionally reduced by using only one of the main engines.

Data Acquisition

The table and the base map (Fig. 2) below exhibit key parameters for the seismic profiles acquired between St. Thomas and St Croix:

Line ID	Date	Time	Nos of shots	Length km
1	19/3/07	3:55-9:38	8-1896	47
2	19/3/07	10:54-16:00	1897-3790	47
3	19-20/3/07	19:57-2:10	3791-6074	57
4	20/3/07	2:35-8:56	6409-8700	57
5	20/3/07	10:00-15:19	8701-10583	47
1001	20/3/07	16:18-20:30	10593-12133	39
6	21/3/07	1:07-5:46	12135-13807	42
7	21/3/07	6:45-12:13	13834-15806	49
8	22/3/07	1:26-7:12	15816-17869	51
9	22/3/07	8:10-12:43	17872-19530	42
10	23/3/07	1:27-13:50	19537-23912	109
11	24/3/07	1:56-8:43	23934-26357	61
12	24/3/07	9:55-13:35	26360-27683	33

Total 681 km

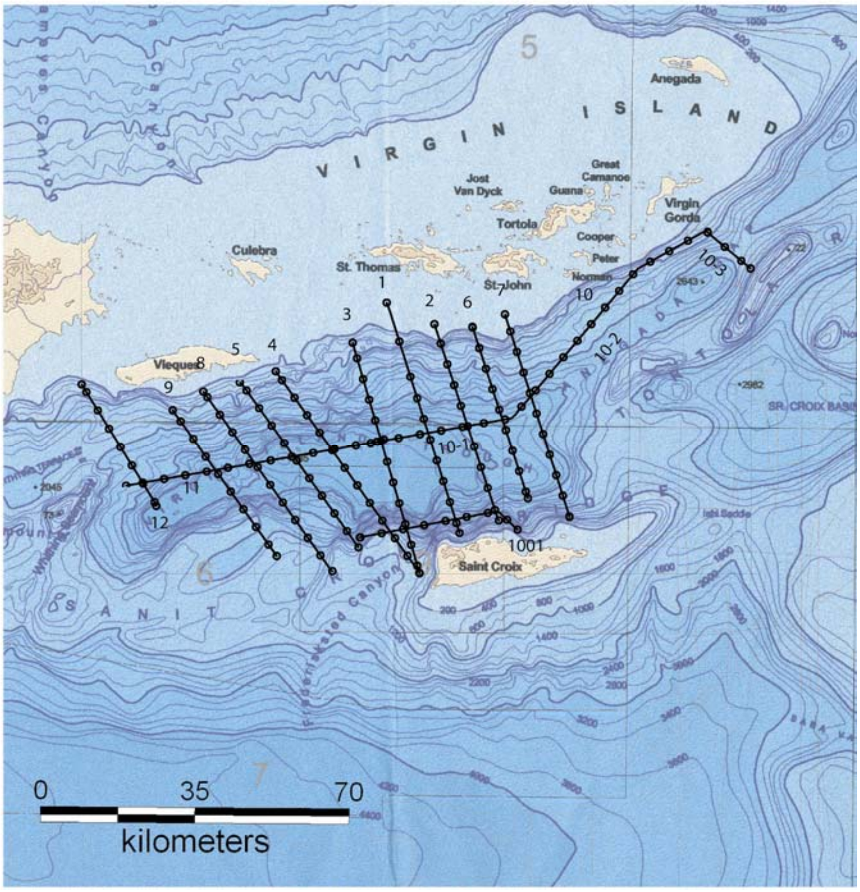


Fig. 2 Seismic tracks of HDMS 'Vædderen', 18-26 March 2007

Brute stack processing

During acquisition of the profiles data was processed to brute stack quality by Geometrics software on the CNT-1 controller. Velocity functions were adjusted on the fly. After the termination of individual profiles a printout of the profiles were performed. The data was reformatted from SEG-D to SEG-Y format and the SP-positions were transferred to the file headers. After that the SEG-Y files were transferred to a PC and imported to "Kingdom Suite" interpretation software.
The seismic profiles shown in Figs. 3 and 4 are presented in a down scaled version with the vertical axes representing 8 sec TWT and with shot point numbers annotated along the horizontal axes.

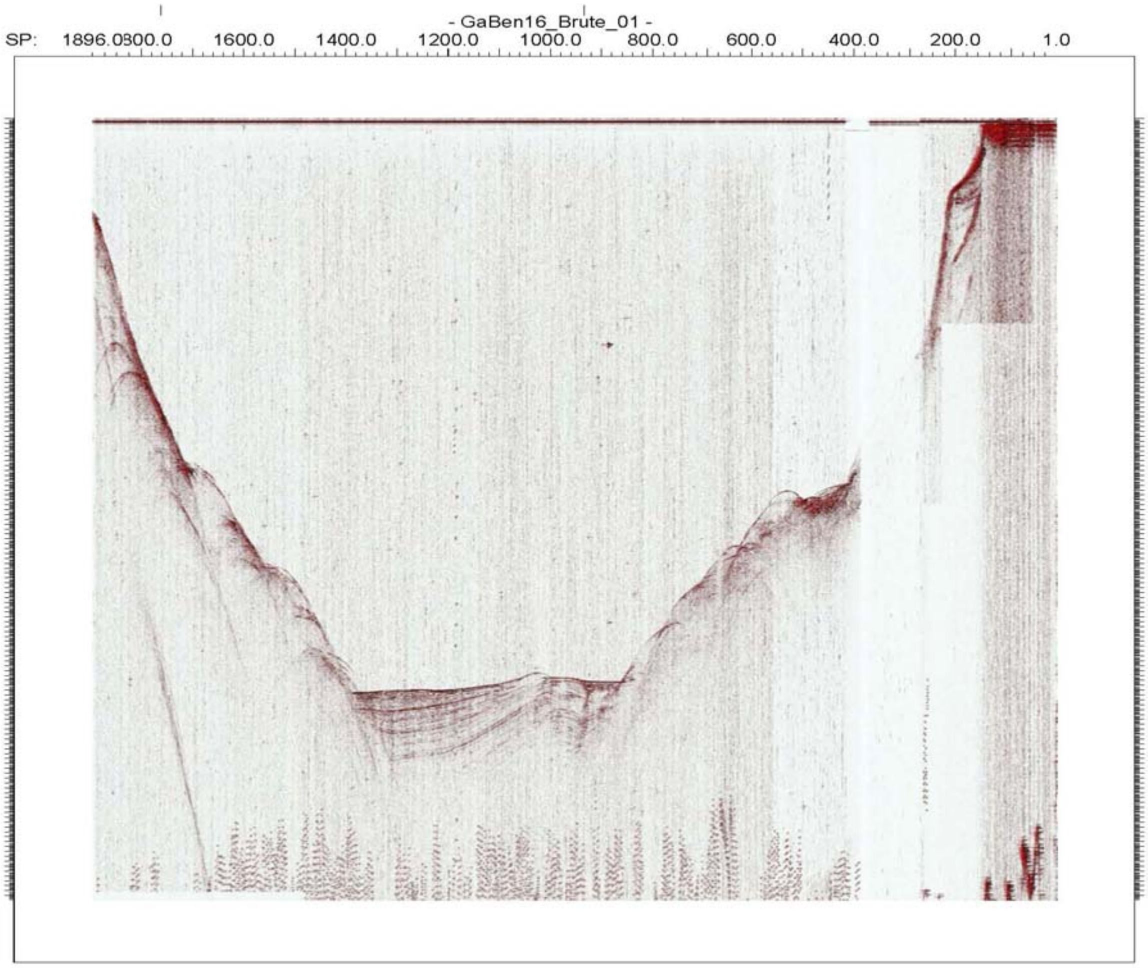


Fig. 3 Example of seismic record (Line 1) showing the steep flanks and sedimentary sequence of the basin

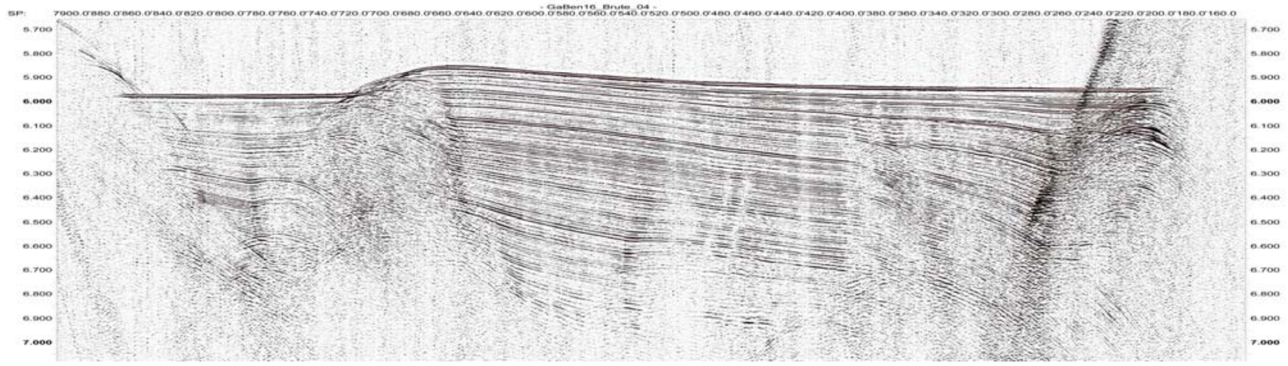


Fig. 4 Seismic section (Line 4) showing details of the central part of the basin

B - Sediment coring activities

Participants

John Boserup, Geological Survey of Denmark and Greenland
Jørgen O. Leth, Geological Survey of Denmark and Greenland
Paul Knutz, Geological Survey of Denmark and Greenland
Helmar Kunzendorf, University of Copenhagen
Marit-Solveig Seidenkrantz, University of Aarhus
Kristina Ravnsgaard Nielsen, University of Copenhagen

Coring strategy

The program involved 3 sampling objectives:

(1) Obtain paleoceanographic records linked to hydrographic variability of three principal water masses in the Anegada-Jungfern Passage: Atlantic surface waters (<600 m), Antarctic Intermediate Waters (AAIW) at depths of 700-1000 m, and North Atlantic Deep Water (NADW) at depths >2000 m. Sampling of sites bathed in AAIW was considered a priority. Two of the coring targets were aimed at re-sampling of sites that was previously cored by shallow penetration (box coring during RV Chapman cruise in 2003).

(2) Retrieve sediment cores located at the distal part of a submarine canyon mouth (e.g. deep sea fan type deposits) that connects to the Salt River Bay on the northern of St Croix, principally to trace sediment flux variability and slope instability linked to catastrophic event, e.g. earthquakes and tsunamis, in the past.

(3) Sampling of shelf sediments off St. Thomas at sites located by the ‘RV Bright Star’ team, based on shallow acoustic surveying conducted parallel to the ‘RV Vædderen’ mission.

The selection of sites was based on seismic profiles gathered during the initial part of the cruise and multibeam echosounder data, as it became it available. Coring was mainly performed during daytime hours over the period 21/3-25/3 while seismic acquisition was resumed during nighttime. A full log of the sampling activities is presented in Table 1 at the end of this chapter.

Conductivity-Temperature-Depth (CTD) profile

At the deepest site in the middle of the basin a CTD measurement was carried out. The equipment was handled by the ships crew in addition to Tommy Nielsen and Jørgen Friis-Christensen, DFU.

The CTD profile (Fig.5) confirmed the data from a previous CTD profile and showed the main water masses of the area: *Caribbean Surface Water* (>50 m water depth): High temperature (27°C) and comparatively low salinities (36 psu).
Atlantic surface waters (50-600 m water depth): High salinities (37 psu) and high but downwards decreasing temperatures.
Antarctic Intermediate Waters (AAIW) at depths of 700-1000 m: Low salinities and oxygen content and decreasing temperatures.
North Atlantic Deep Water (NADW) at depths >1700 m: Stable water mass of comparatively low temperatures and salinities of app. 35 psu.
The CTD measurement was limited by the cable length of 4200 m at this site of approximately 4400 m water depth.

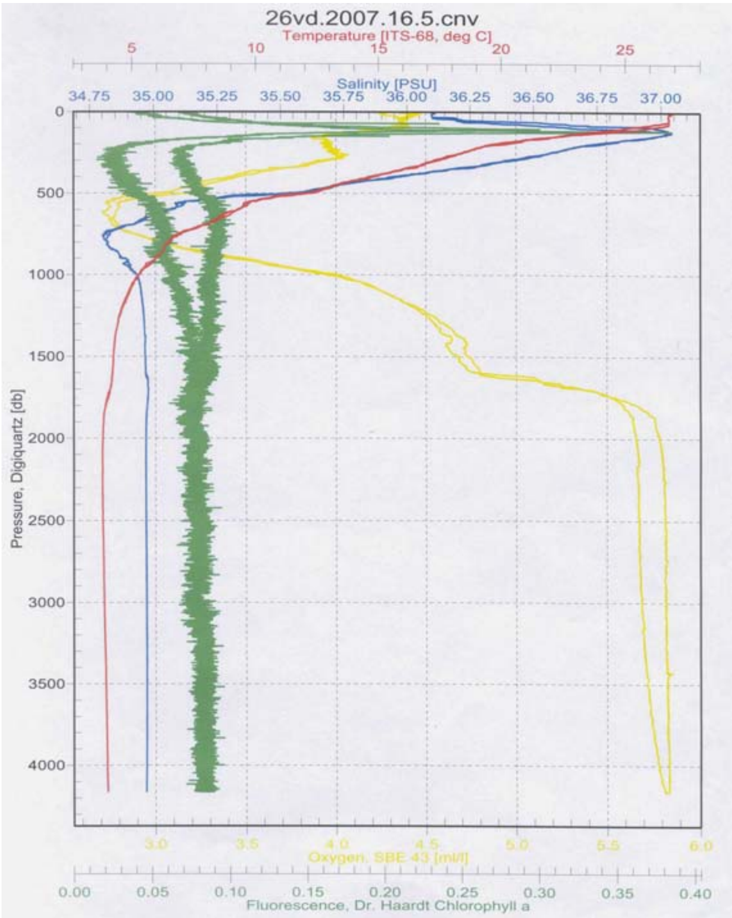


Fig 5 The CTD-profile performed in the Anegada-Jungfern basin. Yellow colour = oxygen; red colour = temperature; Blue colour = salinity; Green colour = Fluorescence. Depth scale to the left in meters. Water depth about 4,200 meters.

Sediment sampling equipment and procedure

The two principal facilities were (1) Box corer (the so-called Brutalis) with a penetration of max. 55 cm and a sample pod diameter of 324 mm, (2) 6 m Gravity Corer with liner diameter of 125 mm and a core catcher consisting of flexible steel lamellas.

Fig. 6 Handling of the gravity corer onboard HDMS "Vædderen".

Onboard was also a 12-m Piston corer, which is the preferred choice for retrieval of paleo-climate, archives from unconsolidated muddy sediments. However, it was not used on this mission due to problems experienced on an earlier Galathea3 leg, and the lag of time for further testing.

CTD was performed on one deep-water station in the middle of the Anegada-Jungfern basin. The CTD profile is presented in Fig. 5. The density data was used by the hydrographic officers onboard HDMS "Vædderen" to adjust the multibeam echosounder data.

The ship's crew operated the ship's winch, crane and the side-mounted A-frame, while the sediment sampling group handled the coring equipment on deck (Fig. 6).

Treatment of Box Core

After returning the box corer to the ship's deck, the quality of the sediment in the boxcorer was evaluated. For box cores containing undisturbed or only tilted sediments, 4-5 sub-samples were retrieved for the planned analysis at home. All the samples were stored in a fridge at 10ºC onboard. At all box corer positions except station GA307-WIN-01BC one of the sub-samples was opened and sliced at 1cm intervals for micropalaeontological studies. The upper 2 cm were sliced at 0.5 cm intervals, where possible. Ethanol was added to the sliced sediment of the upper 15 cm of each core in order to preserve the organic material of living benthic foraminifera.
After the cruise, Rose Bengal was added to the samples in the laboratory at the Department of Earth Sciences, University of Aarhus. The purpose was to colour organic remains to distinguish living from dead foraminiferal specimens.
At each good quality station, a surface sample representing the upper 1 cm sediment was collected and sea-water was added. This sample was stored in a freezer of -80°C for subsequent DNA analysis of benthic foraminifera.

Treatment of Gravity Core

Subsequent to successful sampling the gravity corer liner was sliced into 1m segments and capped at both ends, numbered and store in a fridge at 10 ºC.

Fair weather conditions were experienced during the entire cruise. Summary information from each sampling site in terms of position, sample type, coring operation and sediment description is provided in Table 1.

Results

The cruise resulted in 13 boxcore samples while 2 long cores were obtained using the gravity core system. These gravity cores - GC12 and GC14 - were obtained from a sedimentary unit in the vicinity of the Salt River Bay canyon, characterised by a high seismic transparency (Fig. 7) with weak continuos reflectors some 20-100 m below sea bed.

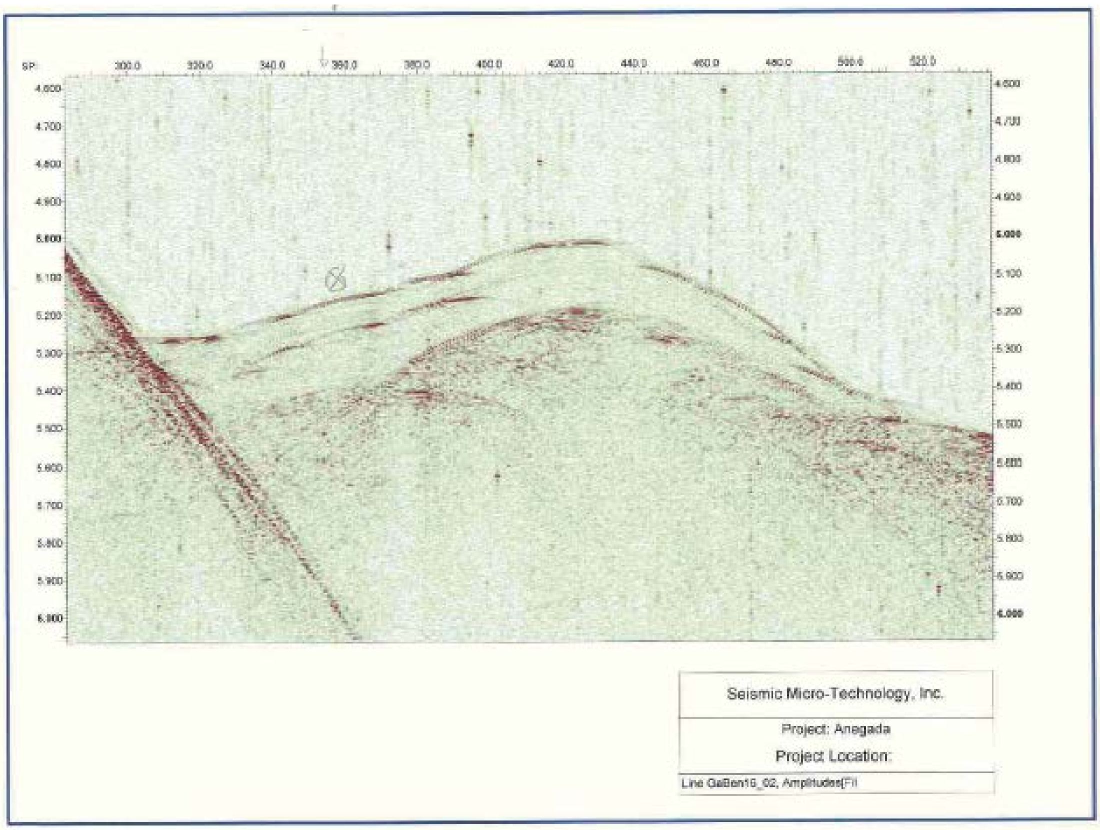


Fig. 7. Seismic section crossing the fan system at depth interval between 3,700 and 4,200 m at the Salt River canyon mouth. Seismic source: GI gun 45/105 cubic inch.

No long gravity cores of the St. Thomas shelf sites were obtained for the paleoceanographic objectives.

The main difficulty experienced on the 'WINMARGIN' cruise was that the gravity corer repeatedly failed to retrieve seabed samples. Although the reason for this problem was not fully understood it was suspected that the seabed was too firm for the corer to penetrate the first 30cm or so. This assumption was based on the observation that many of the box cores that were gathered were observed to be rather sandy and contained a significant amount of marine sponge spicules. Another explanation was that the corer actually penetrated the seabed but that sediment was lost through the core catcher during retrieval. On two occasions mud dripping out of the core head as it was tipped alongside ship suggested that the core catcher was unable to retain the sandy-silty incoherent sediments that predominated in the basin.

In addition to the possible geological factors as a cause for unsuccessful seabed penetration of the gravity corer, the winch-cable system mounted on HDMS "Vædderen" was far from ideal for geological sampling. This was, amongst others, due to the limited monitor control on cable tension that could otherwise serve as a remote sensor of coring progress.

Another problem was that the resolution of the seismic equipment was too low to produce more detailed information on seabed stratigraphy in the upper 20m section. Thus, the selection of core sites could only be based on large-scale morphological features and seismic facies, which gave no indication of present or recent, e.g. Holocene, sedimentation patterns. The deep multichannel profiles indicated depositional patterns related to deep along-slope currents, or contourites, on mid-slope sections (1-3 km depth) (Fig 8). Coring of these contourite units, juxtaposed to areas of seabed erosion linked to deep-water pathways, were attempted at 2 stations but no gravity cores were produced. Another coring target based on the seismic expression was the transparent sedimentary unit interpreted as fan sediments sourced from the Salt River canyon (Fig 7), from which the two gravity cores were recovered on the final day of sampling.

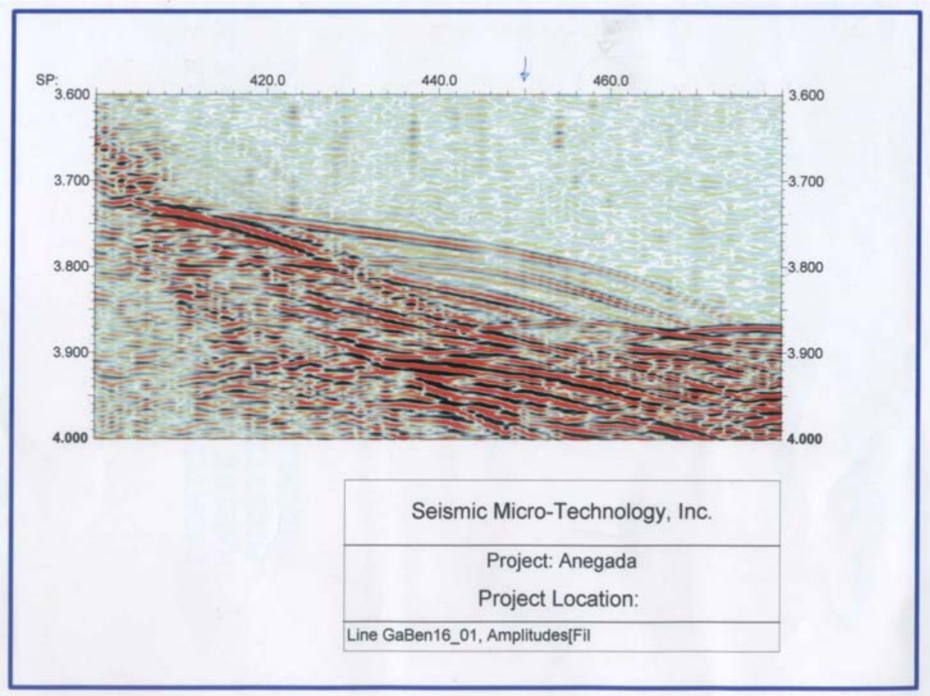


Fig. 8 Seismic multi-channel section indicated depositional patterns related to deep along-slope currents, or contourites, on mid-slope sections. Seismic source: GI gun 45/105 cubic inch.

Several shallow water sites (5-20 m) off St. Thomas were visited as indicated by the parallel investigations by the 'Bright Star' team. However, due to the coarse grained composition of the high-energy seabed environment sampling was limited to box cores.

One of the sites previously visited by the 'RV Chapman' 2003-cruise was re-cored by box coring (also here gravity coring failed). The other had to be abandoned due to time limitations.

A particular visual result of the project was the multibeam echosounder data providing a bathymetric map that covered the entire basin and parts of the shelf areas (Fig. 9)

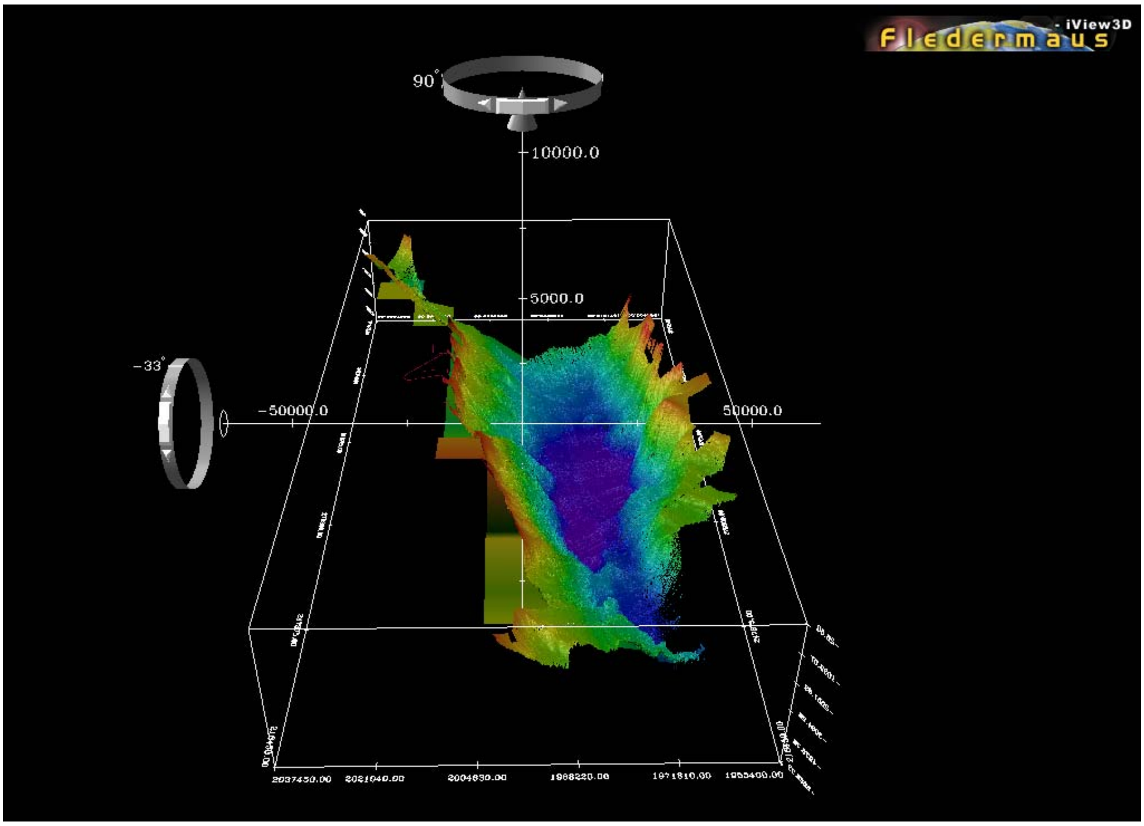


Fig. 9 The multibeam data presented in 3-D showing the configuration of the Anegada-Jungfern basin. View from the west to the east with St. Croix lying to the right and St. Thomas to the left. Blue colour indicates water depths deeper than 4,000 m.

Table 1. Sediment sampling - station data

Date	Station ID GA307-	Latitude	Longitude	Sample type	Subsamples ID*	Sample depth/penetration (cm)	Water depth (m)
03/21/07	Win-01	17^{0} 52,9810	-64^{0} 47,0210	Box corer	BC01,-02	14	3988
03/21/07	Win-02	17^{0} 45,1805	-64^{0} 58,2614	Box corer	BC01-BC05	32	1026
03/21/07	Win-02	17^{0} 45,0892	-64^{0} 58,2779	Gravity corer	GC01,-02, +2 cc	26, 30	1025
03/22/07	Win-03	17^{0} 58,3374	-65^{0} 01,0074	Box corer	BC01-BC05	30	4352
03/22/07	Win-03	17^{0} 57,7640	-64^{0} 59,6450	Gravity corer	GC	28	4405
03/22/07	Win-04	18^{0} 13,9285	-64^{0} 32,6129	Box corer	BC01-BC05	22	1745
03/22/07	Win-04	18^{0} 13,7896	-64^{0} 32,4966	Gravity corer	GC	41	1798
03/23/07	Win-05	18^{0} 08,2577	-64^{0} 43,1540	Box corer	BC01-BC05	12	1634
03/23/07	Win-06	18^{0} 05,4300	-64^{0} 56,5200	Gravity corer	GC	40	2875
03/23/07	Win-06	18^{0} 05,4300	-64^{0} 56,5200	Box corer	BC01-BC05	25-30	2875
03/24/07	Win-07	17^{0} 45,9240	-65^{0} 01,5212	Box corer	BC01-BC05	11	763
03/24/07	Win-07	17^{0} 45,9258	-65^{0} 01,3141	Gravity corer	GC (1x cc)	3-5	746
03/24/07	Win-08	18^{0} 19,9165	-64^{0} 59,9815	Box corer	BC01-BC04	12	27
03/24/07	Win-08	18^{0} 19,9165	-64^{0} 59,9815	Gravity corer	No recovery	0	27
03/25/07	Win-09	18^{0} 20,0050	-64^{0} 59,6120	Box corer	No recovery	0	29
03/25/07	Win-09	18^{0} 19,9730	-64^{0} 59,5289	Box corer	BC01-BC05	12	30
03/25/07	Win-09	18^{0} 19,8520	-64^{0} 59,6260	Gravity corer	No recovery	0	28
03/25/07	Win-09	18^{0} 19,9080	-64^{0} 59,5400	Rumohr corer	No recovery	0	30
03/25/07	Win-10	18^{0} 19,9950	-65^{0} 00,0850	Box corer	BC01-BC04	15	28
03/25/07	Win-11	18^{0} 17,0495	-64^{0} 54,2620	Box corer	BC01-BC04	12	23
03/25/07	Win-12	17^{0} 50,8000	-64^{0} 48,7290	Gravity corer	GC01-06	488	3960
03/25/07	Win-13	17^{0} 53,9660	-64^{0} 47,5220	Gravity corer	GC01-02	80	3772
03/25/07	Win-14	17^{0} 53,8860	-64^{0} 47,5320	Gravity corer	GC01-05	c. 400	3774
03/25/07	Win-15	17^{0} 42,7110	-64^{0} 53,7920	Box corer	BC01-BC04	37	293

**) Sub-sampling procedure: 4 sub-samples taken out for various analyses/archiving, 1 sub-sample sliced onboard for micropaleontology. cc= core catcher*

2. RV *'Bright Star'* - Shallow seismic survey in coastal waters of St. Thomas and St. John

A. Kuijpers, J.B. Jensen*, R. Endler** and G. Nickel***

**   Geological Survey of Denmark and Greenland, Copenhagen*
*** Baltic Sea Research Institute ('IOW'), Warnemünde, Germany*

General

Due to persistent technical problems with the engine of UVI's RV *'Willie Mac II'* , prior to arrival of the Galathea3 expedition RV *'Bright Star'* was made available by UVI as an alternative platform for the shallow seismic survey of coastal waters of St. Thomas and St. John. Purpose of this survey was to investigate the sub-bottom structure and architecture of the seabed in this area, and to find suitable coring positions for HDMS '*Vædderen*'. The 11-m long *'Bright Star'* (Fig. 1) with plenty of open deck space proved to be extremely stable in rougher seas and highly suitable for the seismic work. For docking, on St. Thomas the facilities of UVI's Marine Science Department could be used (14 – 16 March, 21-23 March), whereas on St. John docking was at facilities of UVI's 'VIERS' station (19-21 March).

Fig. 1. RV 'Bright Star' with ('C Boom') boomer and streamer in Brewers Bay. Photo UVI, G. Metz

Survey methods

High-resolution sub-bottom profiling – SES 96 parametric echo-sounder

High resolution acoustic sub-bottom profiling was performed using the parametric sediment echosounder SES96- Standard (Baltic Sea Research Institute, 'IOW', Warnemuende, Germany). This new type of shallow water parametric sediment echosounders was developed in the frame of the joint project "Adaptive seismo-acoustic systems for the Baltic Sea"; carried out by the Rostock University and the Baltic Sea Research Institute; granted by the German Federal Ministry of Education and Research, project - no 03G0513A. Based on components developed by the Underwater Acoustics Research Group of Rostock University, the INNOMAR Technology GmbH (www.innomar.com) developed the product line of SES 96 / SES 2000 parametric echo-sounders.

Parametric echo-sounders work both as low-frequency sediment echosounders and as high-frequency narrow beam echsounders (to measure water depth). They make use of the so called "parametric" effect which produces additional (secondary) frequency components through non-linear interaction of two signals with high, slightly different (primary) frequencies at high sound pressures. The new, low (secondary) frequency components propagate within the narrow cone of the high (primary) frequencies. Therefore, the footprint size is comparably small and both lateral and vertical resolution are significantly improved. The directivity pattern of the low frequency components shows no significant side lobes and remains nearly constant for different secondary frequencies. The insonified volume is the same and comparable results are obtained for different secondary frequencies. Parametric systems have a high system bandwidth and can therefore transmit short pulses without ringing (e.g. 1 period of 12 kHz). This makes parametric systems particularly useful for high resolution surveys in shallow water areas. Furthermore, short pulses, narrow beams and the absence of side lobes result in less volume and bottom surface reverberation compared to linear systems. This improves the signal to noise ratio and therefore the usable depth range (penetration depth).

Fig. 2 Installation of the transducer array, DGPS antenna and motion reference unit on the side of the boat.

The parametric SES96 Standard sediment echosounder is designed for operation in shelf areas with water depth up to 400 m. It consists of a main device and a transducer array. The transducer array, was mounted on the side of the boat (see Fig. 2). The main device contains transmitters, receivers and modules for analogue and real time signal processing. Analogue to digital converters (ADC) are used for digitizing the receiver signals with 16-bit resolution. All data are stored digitally on hard disk including navigational data obtained from a Trimble DGPS. A motion reference unit, mounted above the transducer array, was used to correct for the boat's movement. A detailed description of the SES – echosounder system is given at www.innomar.com, with the main transducer and transmitter parameters listed in below table .

Table 1 *Main transducer and transmitter data of the SES96 Standard parametric echo-sounder*

Transducer	Transducer type Z (staves 16*1) Non-linear transmitter, linear receiver, aperture 3.6°, $(0.2*0.2)m^2$
Transmitter	Primary frequency: 100 kHz Secondary frequency: 4, 5, 6, 8, 10, 12 kHz Option: multi frequency signals Mode 1: 6 and 12 kHz (166µs) Mode 2: 4, 8 and 12 kHz (250 µs) Transmitting channels: 16

The main advantages of the SES96 echosounder are its high spatial resolution and the information contained in raw data of both HF and LF channels. This is particularly important for acoustical sediment classification

The SES96 echosounder worked very reliably during the whole cruise. In general the data quality was good even though the conditions were often unfavorable because of the wind conditions and relatively rough seas. Some interference occurred with the boomer data acquisition, which is attributable to the partly overlapping frequency range and the high firing rate of both devices.

Shallow seismic data acquisition – 'C-Boom'

The C-Boom LVB is a compact, boomer system with a working voltage adjustable between 400 and 600 Volts DC. It is a high resolution seismic instrument, which can work at water depths from one meter to more than hundred meters, providing sub-bottom penetration exceeding 80 m in soft sediments. Together with an 8-element, single-channel streamer, the boomer tow-fish with its limited weight of *c*. 35 kg is extremely suitable for handling on smaller vessels. Even under relatively rough seas (Fig. 3), the boomer proved to produce good data quality.
The energy used by the system (100 J) provides an acoustic output of (re 1uPa @ 1m) -200dB with a dominant frequency of 1760Hz. This produces high-resolution records with a vertical resolution better than 0.3 m. The maximum firing rate is up to 6 per second. The required power supply is specified at 110 / 220 Volts AC (50/60 Hz), using a 1.5 KVA generator. In our case, power supply for both the sediment-echosounder and the boomer system with GPS navigation as well as digital and analogue (sediment-echosounder) recording instruments was provided by a 3.5 KW Honda electrical power generator (Fig. 3).

Fig. 3 Boomer data acquisition under relatively rough sea conditions. To the left the Honda 3.5 KW generator

Chronological

March 13, 2007 (afternoon)
RV *'Bright Star'* at UVI's docking facilities, St. Thomas; inspection of the vessel with regard to installation of various equipment, next day

March 14
Mobilisation and installation of acoustic and seismic gear (docking at UVI); test profile, line WM07-01, Brewers Bay, SW Road. Wind 5-6 Bft, NNE.

March 15
Brewers Bay, SW Road: lines WM07-02 to WM07-11. Wind 3-5 Bft, (E)NE. Docking at UVI

March 16

Transit from UVI's dock to area SW of Charlotte Amalie; deployment of gear near 'Long Point'. Lines WM07-12 to WM07-21. Transit to UVI's VIERS Station, south coast of St. John. Wind 2-4 Bft, later decreasing, ENE.

March 17-18

VIERS Station – no survey activities

March 19

Transit to Reef Bay and waters between St. Thomas and St. John (Pillbury Sound). Lines WM07-22 to WM07-30. Wind 5-6 Bft, ESE, later decreasing to 3 Bft , ENE. Docking at VIERS.

March 20

Transit to Coral Bay, SE of St. John. Due to high swell / rough seas deployment cancelled here, and return, heading west for Pillsbury Sound. Lines WM07-31 to WM07-40. Wind *c*. 4 Bft, ESE. Docking at VIERS.

March 21

Transit to Buck Island, south of St. Thomas, for deployment of gear leeward of the island. Lines WM07-41 to WM07-47. Retrieval of gear near Flat Cay, south of St. Thomas airport. Wind 4 Bft, ENE, later ESE, decreasing 2-3 Bft. Docking at UVI facilities, St. Thomas.

March 22

Transit to Pillsbury Sound. Lines WM07-48 to WM07-52. Wind 4-5 Bft, ESE. Docking at UVI.

March 23

Brewers Bay and SW Road. Lines WM07-53 to WM07-59. Wind 4-5 Bft, ESE. Afternoon: docking at UVI and demobilization of the equipment.

Preliminary results and conclusions

Despite of some days with intermittent periods of stronger winds of around 5 Bft, no time was lost due weather conditions. In addition, no major failure of the instruments was observed. In total around 270 km of sediment echo-sounding and shallow seismic data were acquired. An overview of the seismic tracks is given in Fig. 4, which also indicates (in red) the location of sub-bottom records shown in Figs. 5-7.

Preliminary conclusions are:

- A regional reflector is found at 25-35 m below present sea level throughout the study area (see Fig. 5, 7). This reflector is also present between St. Thomas and St. John and may represent an abrasion platform under lower, i.e. early Holocene or late Pleistocene, sea level conditions. In many cases this reflector seems to be the base of offshore coral heads.

- The sediment distribution (e.g. thickness) pattern and large-scale current-induced bedforms (Fig. 5, 6) south of St. Thomas indicate a strong westerly sediment transport. This is also suggested by relatively thick, partly stratified, sediment sequences found in Brewers Bay and adjacent part of the Southwest Road, an apparently more sheltered area when compared with sedimentary conditions elsewhere.

- Based on acoustic and seismic characteristics, various sediment units in most of the area appear to have a mainly sandy character. Only in Brewers Bay evidence has been found for the presence of an older (? early Holocene) sediment unit with clay intercalations (Fig. 7, stratified unit).

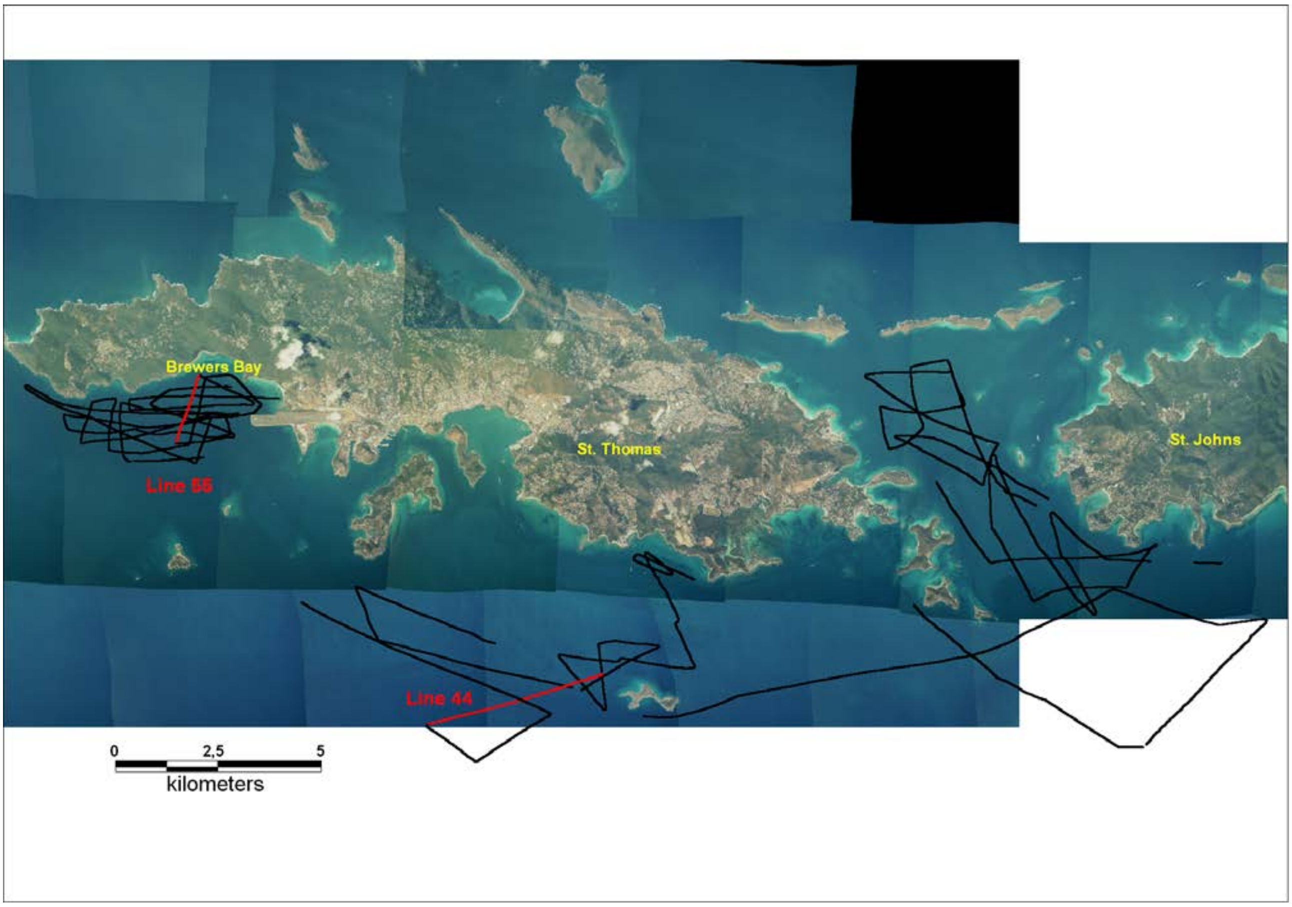


Fig. 4 Overview of survey lines of RV 'Bright Star', 14 – 23 March 2007. Red lines indicate the position of sub-bottom records shown in Fig. 5-7

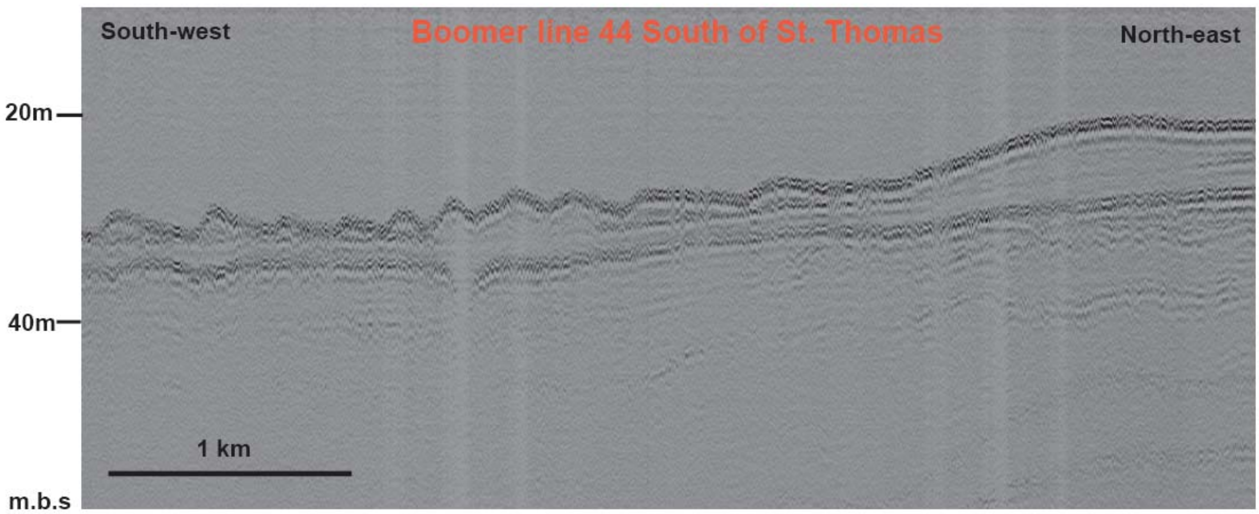


Fig. 5 Boomer record (line 44, Fig. 4) from south of St. Thomas showing large dunes (see also Fig. 6) and a well-defined sub-bottom reflector between c. 35 and 30 m depth below present sea level. This reflector has been found to be widespread in the entire study area at depths between about 25 and 35 m.

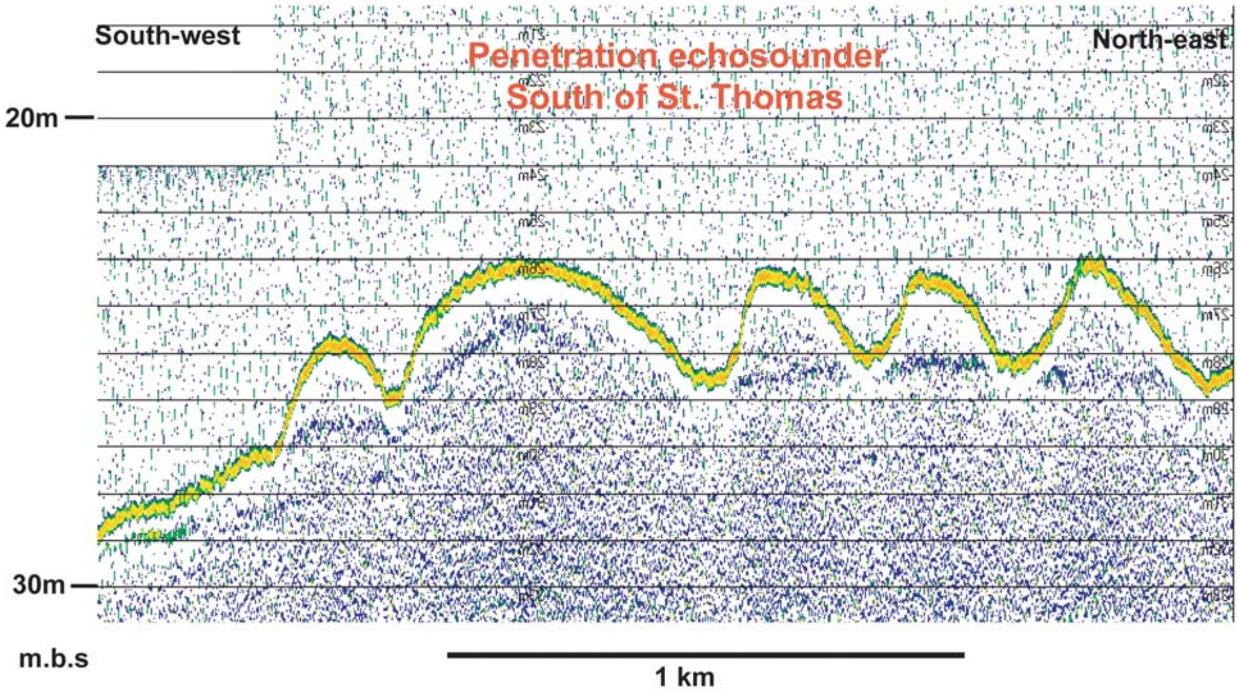


Fig. 6 Sediment echo-sounder record of large sand dunes with (steep) leeside slopes facing west indicative of westerly sediment transport (for position, see line 44, Fig. 4)

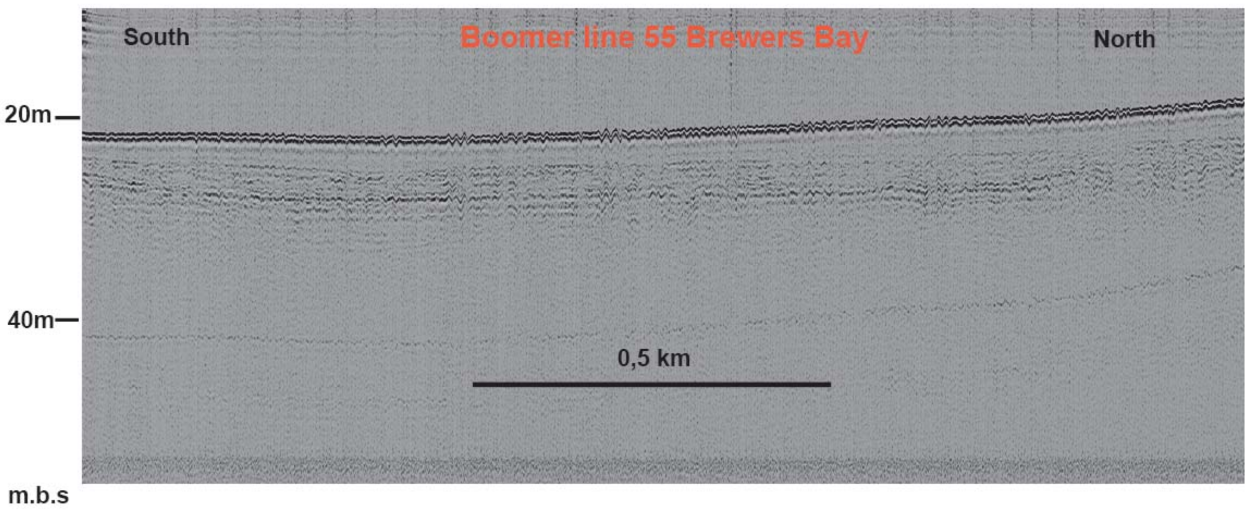


Fig. 7 Boomer record from Brewers Bay showing a more distinct reflector at 25-28 m below sea level. This reflector underlies an acoustically stratified unit, whereas a more transparent, 2-5 m thick unit forms the top of the sequence.

3. Field report from Galathea3 WINMARGIN – Land Team St. Croix.

Jesper Bartholdy and Jørn B. Torp Pedersen , University of Copenhagen

Participants

Jesper Bartholdy
Jørn Bjarke Torp Pedersen
Mikkel Fruergaard
All at the Institute of Geography and Geology, University of Copenhagen.

Period and purpose

This field campaign was carried out in March 2007 with the purpose of gathering as much information as possible about Holocene coastal deposits on St. Croix. The results are eventually to be combined with results from the other WINMARGIN teams in order to support the combined purpose of this project see http://www.galathea3.dk/dk/Menu/Forskning/West+Indies+Marine+Geoscience+Investigations

Methods

Three types of coring techniques were used according to sediment type and purpose: Vibra-coring, hand auguring (using Eijkelkamp equipment) and Monolithe-sampling.

Vibra-coring was used in flooded areas. It utilizes that vibrations from a concrete vibrator can make an aluminum pipe penetrate loose water-saturated sediments. The technique allows cores to be taken of up to a maximum of 6 m (Fig. LT1). On land where compacted dry sediments didn't allow the vibra-coring technique to function, cores were taken using the Eijkelkamp hand auguring (Fig. $LT2_{left}$). This technique does not allow cores to be gathered for lab-analyze. Only core description in the field and sample collection are possible. Monolithe-sampling consists of a steel mantle which is hammered into the wall of a dug hole (Fig. $LT2_{right}$). The technique enables precise cores to be taken of the upper sediment layers on land (inter-tidal) without compaction. In this way surface sediments can be sampled undisturbed and suitable for analyze of sedimentation rates by e.g. ^{210}Pb-dating. Where possible, corings were made in transects perpendicular to the landscape elements and the transect topography were subsequently surveyed by means of a total station. If this wasn't possible, the core-level was estimated by means of water depth and tide gauge observations.

Fig. LT1 Vibra-coring on the open coast off of Great Salt Pond, St. Croix.

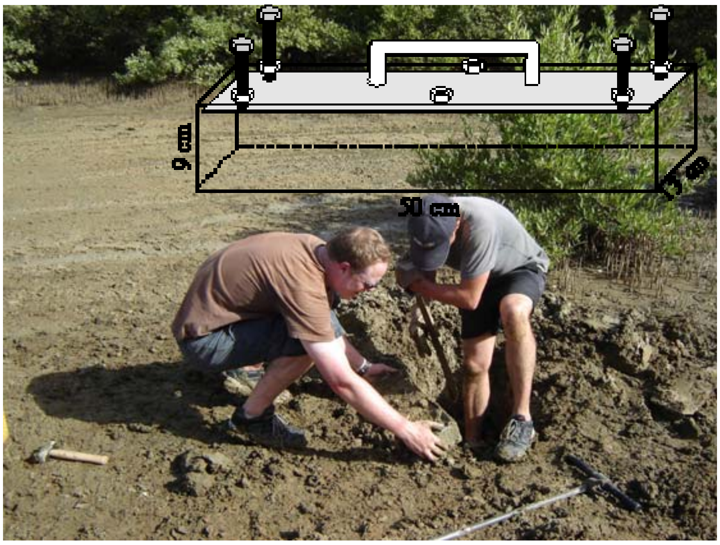


*Fig. LT2. **Left**: Auguring with Eijkelkamp equipment in the inter-tidal zone of the inner part of Great Salt Pond Lagoon. **Right**: Collecting a Monolith-sample of the upper part of the inter-tidal sediments at the inner part of Great Salt Pond Lagoon. The monolith-sampler is sketched in the upper right.*

Study sites

Based on a detailed reconnaissance of all coastal areas on St. Croix, four areas were selected: Salt River Estuary, Sandy Point (Westend Saltpond), Great Salt Pond and Altona Lagoon (see Fig. LT3).

Salt River Estuary

Apart from being the only well investigated clastic depositional environment on St. Croix (e.g. *Hubbard, D.K. 1992. Hurricane-induced sediment transport in open-shelf tropical systems – An example from St. Croix, U.S. Virgin Islands. Journal of Sedimentary Petrology 62 #6, 946-960.*)
Salt River Estuary represents the upper part of a submarine canyon, which comprised one of the key locations for coring and topographic/seismic surveying carried out by the research vessel Vædderen on this part of the Galathea III expedition. From Hubbard (1992) it is known that during hurricanes, sediments are transported in land as well as towards the sea through this canyon with an exceptional high dynamical impact. It is, thus, expected that hurricane layers in cores from this landward end of the canyon system (for location see Fig. LT4) can be correlated with layers from the canyon delta in its distal end on deep water.

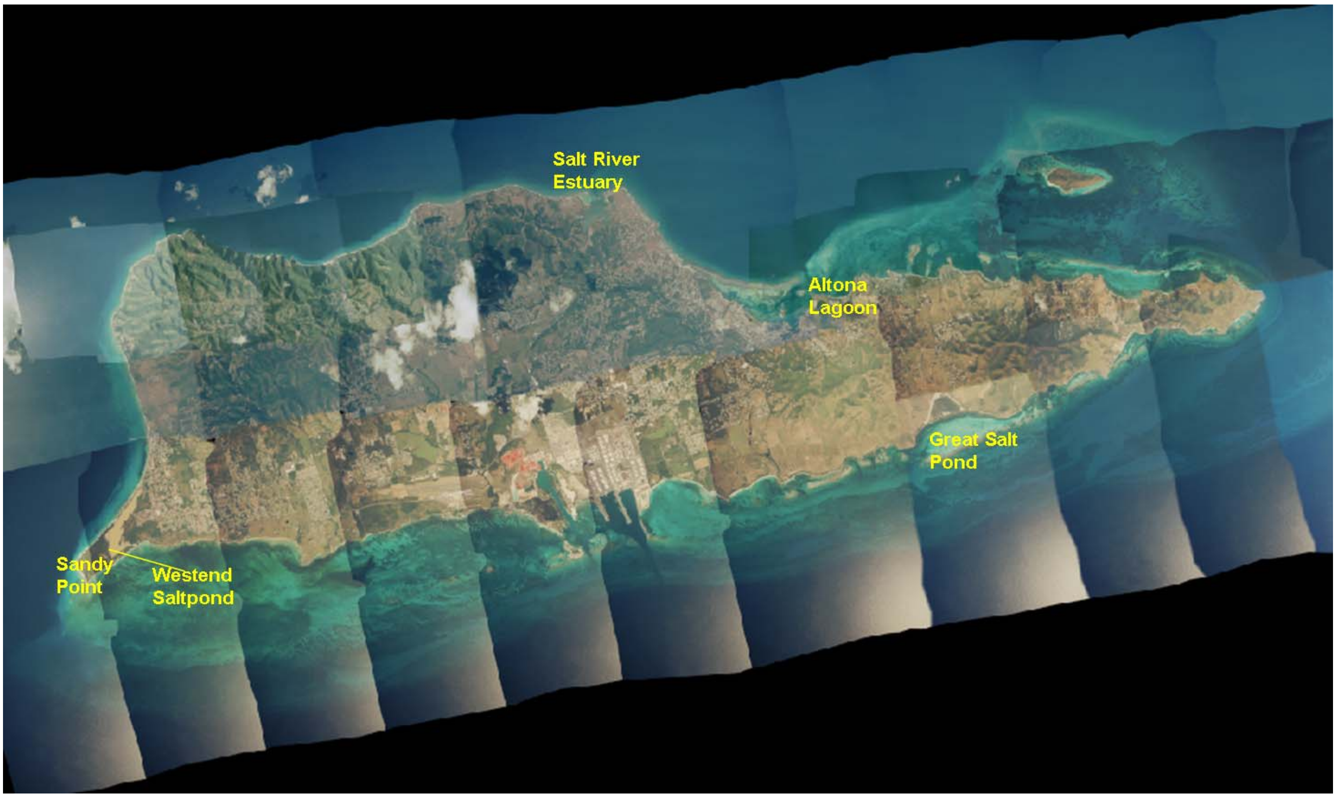


Fig. LT3 Arial photo mosaic of St. Croix with indications of the four locations selected for coring. For scale, the island is 36 km long (east/west).

Fig. LT4 Core locations in Salt River Estuary, St Croix.

Western Saltpond

Sandy Point is making up a cuspate foreland on the west-coast of St. Croix. It is attached to land in a tombolo like construction by two barriers between which a salt lake has been formed. This location is the only depositional environment on St. Croix facing the direction of tsunamies like the one which hit the island in 1867. It might therefore be expected that if evidence of tsunamies are to be found in the sedimentary record, the most likely place to look for this is in this lake, Western Saltpond. The area was cored in a line directed South/East – North/West from the exposed beach over the southern barrier across the lake to the northern barrier (Fig. LT5).

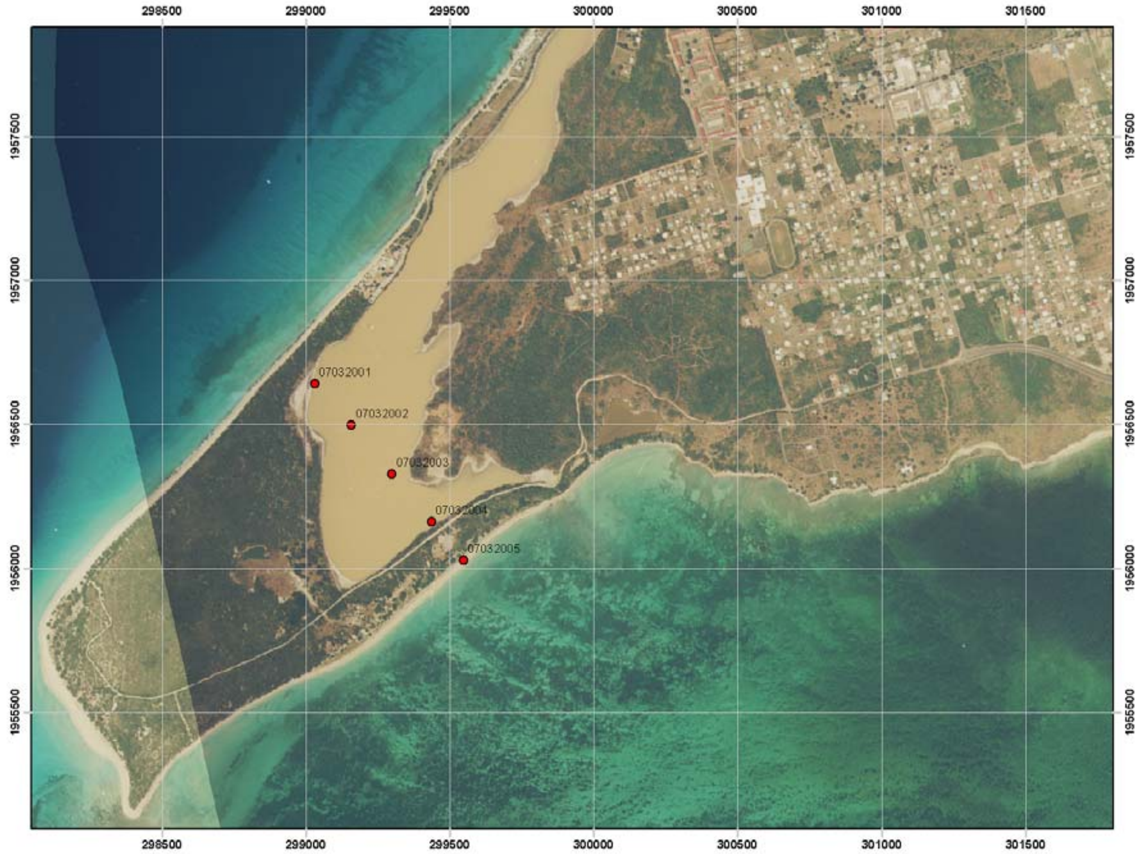


Fig. LT5 Core locations in Western Saltpond at Sandy Point on St. Croix.

Great Salt Pond

Being a typical micro tidal lagoon with an open (although mangrove covered) tidal inlet, Great Salt Pond is most likely among the most efficient natural sediment traps in the coastal environment of St. Croix. This was confirmed by the presence of a thick sticky mud-layer at the surface in the lagoon, and the sedimentation rate is expected to be relatively high in this area. Therefore, not only vibra-coring and hand auguring, but also monolith-sampling were carried out at this location. The core locations are shown in Fig LT6. They are placed in a semi (mangrove swamp) straight line across the barrier and the central part of the lagoon.

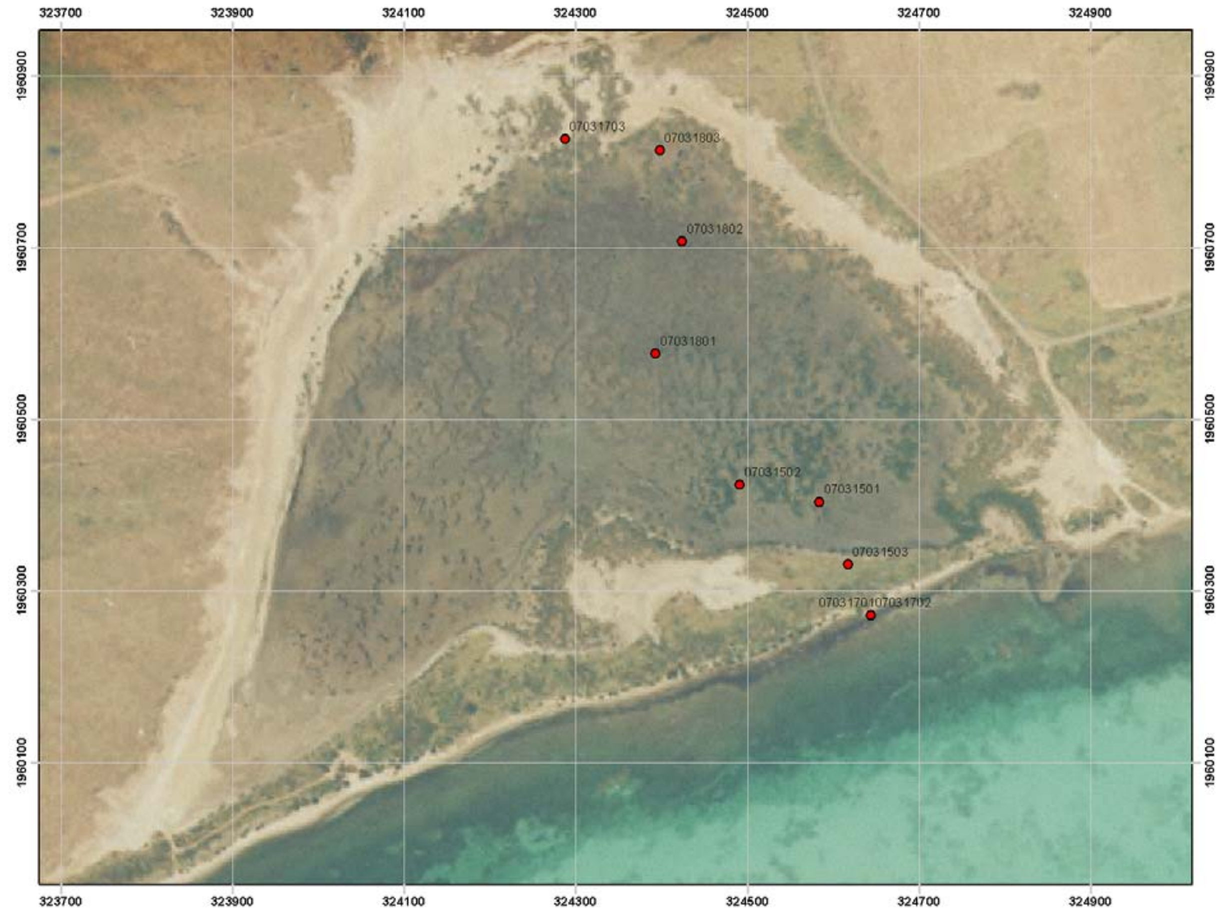


Fig. LT6 Core locations in Great Salt pond, St. Croix.

Altona Lagoon

Altona Lagoon was originally only chosen to be subject to only one vibra-core in its inner part, in order to be able to describe lagoonal sedimentation also from the north side of the island. The bottom sediment of this core, however, turned out to be a sediment which in the field was interpreted as being very similar to peat from temperate climate regions. As a result of this finding two more corings were carried out in the inner part of what is now interpret as a former now transgressed lake (Fig. LT7).

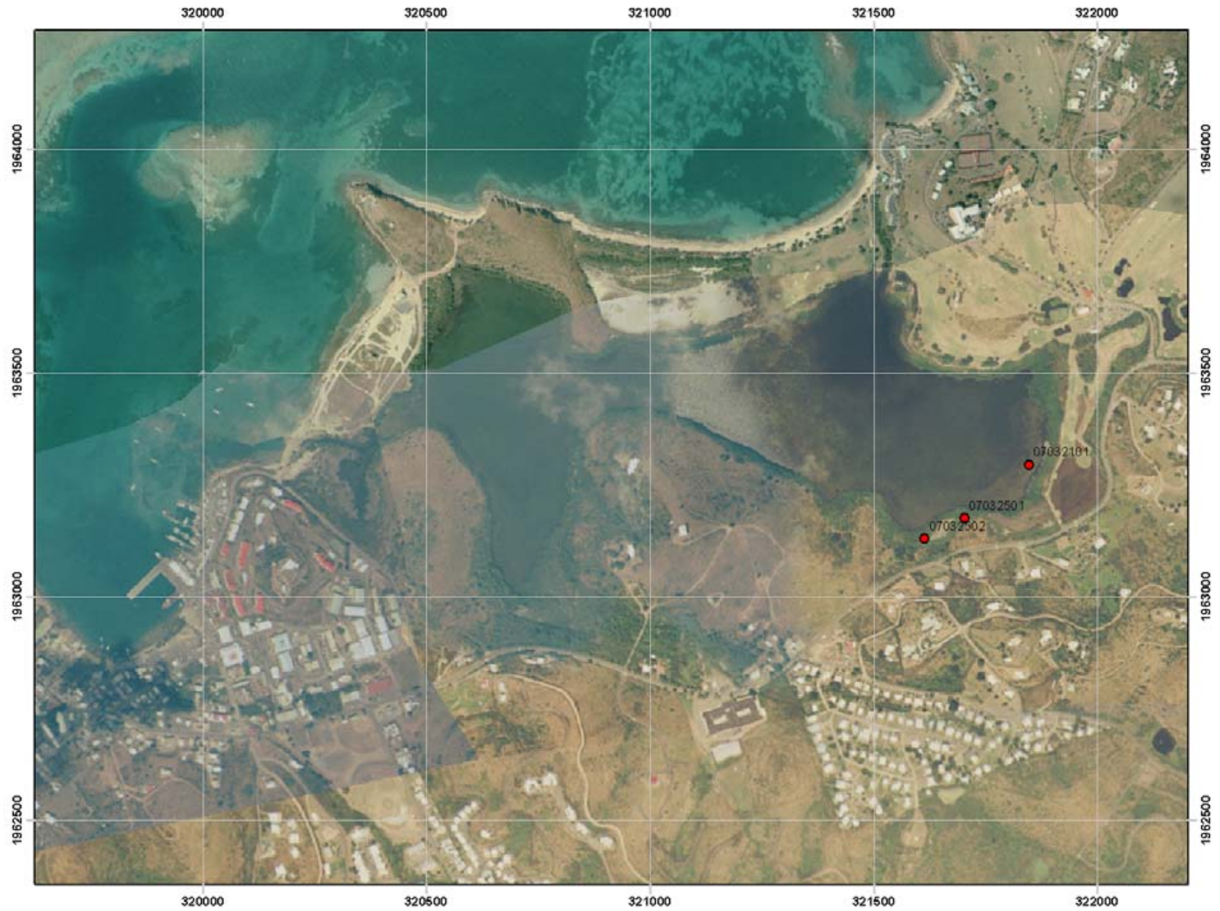


Fig. LT7 Core locations in Altona Lagoon, St. Croix.

Results

By now the only results, apart from the above mentioned observations, are represented by the field coring archive which is copied on the following page (in Danish). The surveyed lines will be constructed as soon as we have received bench mark information from the National Park Service on the island. The cores are brought home and are right now (May/June-2007) in the process of being scanned before they will be opened. A total of 20 vibra-corings (38.77 m), 3 Eijkelkamp corings (5.36 m) and one monolith-sample (0.5 m) have been collected. A list of coring data is presented below Table 1.

Table 1 – St. Croix coring data

Core ID	Latitude*	Longitude*	Time (hh:mm)	Internal (m)	External (m)	Depth (m)	Total barrel length (m)	Internal after retrieval (m)	Core length (m)
07031301	1965786	313502	14.58	2.45	0.53	0.59	3.16	2.45	0.71
07031302	1965786	313502	14.26	2.11	1.75	0.64	2.69	2.04	0.65
07031303	1965732	313501	15.32	1.22	0.90	1.31	3.78	1.26	2.52
07031401	1965478	313524	11.48	0.95	0.31	0.30	3.38	0.91	2.47
07031402	1965518	313514	12.48	0.85	0.23	0.87	5.80	1.10	4.70
07031501	1960404	324584	13.40	0.83	0.43	0.45	3.63	0.85	2.78
07031502	1960424	324491	14.55	0.71	0.36	0.29	3.65	0.78	2.87
07031503	1960331	324617	15.37	0.87	0.33	0.24	3.80	0.92	2.88
07031701	1960272	324644	11.05	0.30	0.20	0.35	2.46	0.78	1.68
07031702	1960272	324644	11.40	0.60	0.43	0.37	3.36	0.50	2.86
07031703	1960827	324287	13.30	1.99	1.25	0.02	2.35	1.97	0.38
07031801	1960577	324393	13.55	0.80	0.51	0.44	2.04	0.86	1.18
07031802	1960708	324424	14.40	0.83	0.44	0.36	2.57	0.87	1.70
07031803	1960814	324398	15.15	0.29	0.14	0.06	0.99	0.19	0.80
07032001	1956642	299030	11.05	1.07	0.53	0.46	3.16	1.10	2.06
07032002	1956497	299157	12.02	1.61	1.16	1.08	2.55	1.50	1.05
07032003	1956327	299298	13.03	1.98	1.45	0.63	3.27	0.09	3.18
07032004	1956162	299436	13.42	0.96	0.44	0.33	2.71	0.94	1.77
07032005	1956027	299547	15.05	0.62	0.55	0.00	1.30	0.60	0.70
07032101	1963295	321847	13.30	2.27	0.78	0.67	3.90	2.07	1.83
E07032501	1963175	321702							1.62
E07032502	1963129	321613							2.14
E070322-01	1960843	324362							1.60
M070322-01	1960843	324362							0.50

*) UTM WGS84