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CAGE_14-5JM
October 07-18-2014

Cruise Report
FF Helmer Hanssen

Fram Strait – NW Svalbard

Longyearbyen – Longyearbyen
07 October 2014 – 18 October 2014

Chief Scientist: Jürgen Mienert
Master: Hans Hansen

With contributions by: Giuliana Panieri, Friederike Marie Luise Gründger; Weil-Li Hong, Joel Johnson, Andreia Plaza Faverola, Pår Jansson, Aleksei Portnov, Katia Carbonara, Kate Alyse Waghorn

RV Helmer Hanssen, 18.10.2014

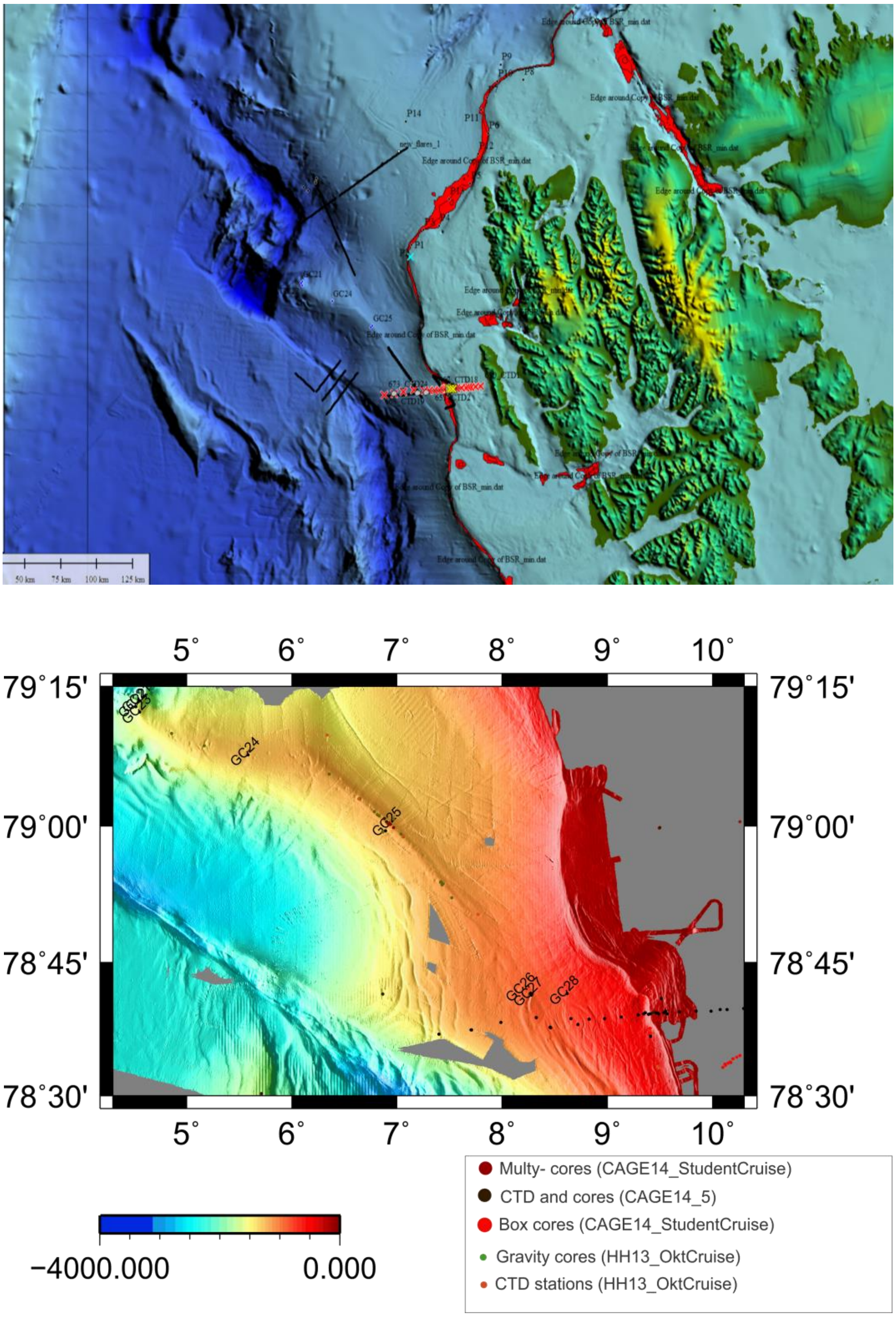

Figure 1 a: Overview map showing the working area off NW Svalbard in the Fram Strait (squares). Cruise CAGE_14-5JM started from Longyearbyen (LYR), Svalbard on 07-10-2014 and finished in Longyearbyen on 17-10-2014. The work concentrated on gas flares at the shelf off Prins Karls Forland (PKF), water mass distributions, gas hydrates at Vestnesa Ridge (VR), the Knipovich Ridge (KR) and Molloy transform (MT), and gas hydrates and submarine slides at SFZ. The Knipovich Ridge is an ultra-slow and obliquely-spreading northernmost extension of the Mid-Atlantic Ridge system (Crane et al., 2001).

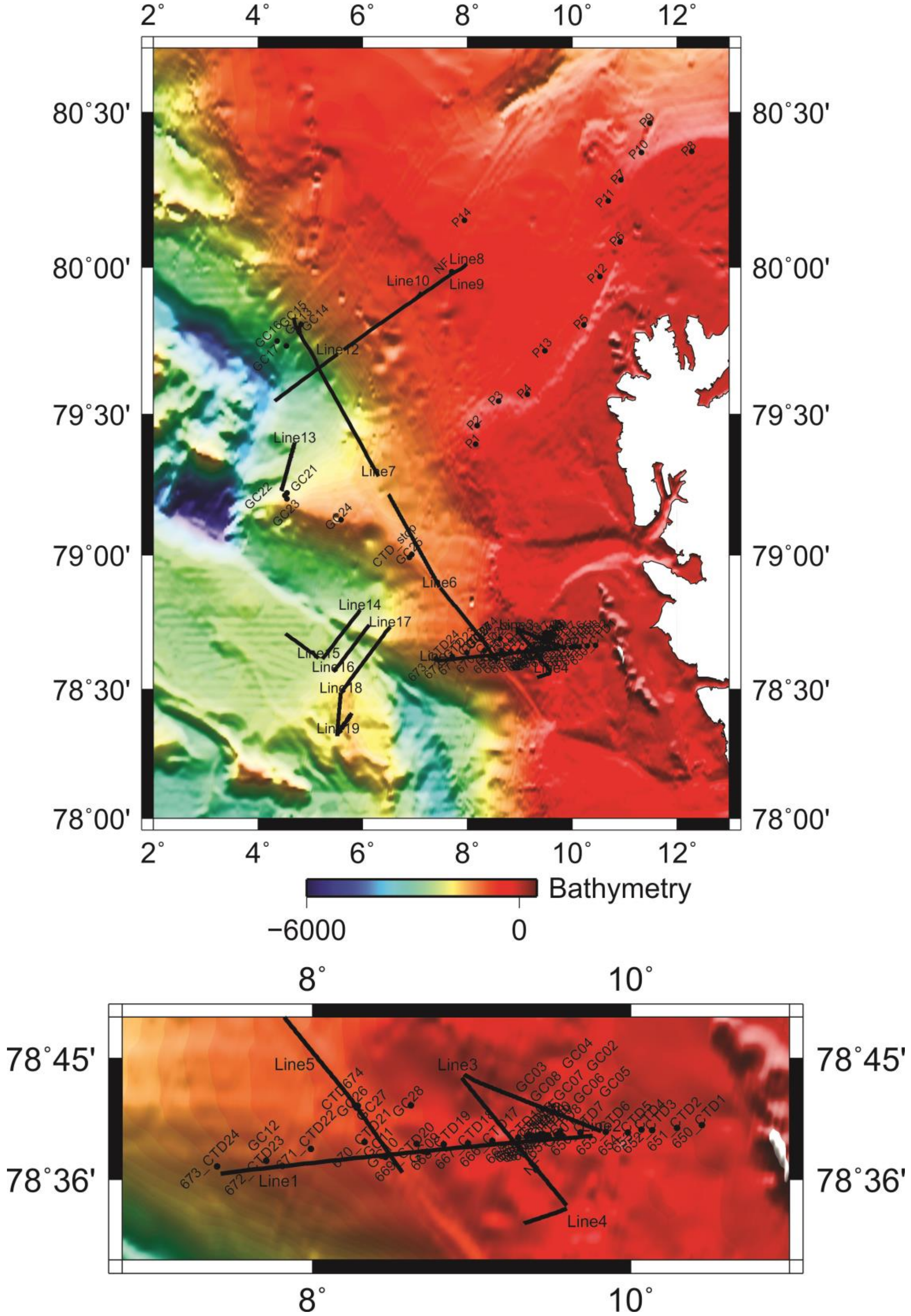

Figure 1 b: Overview map showing the overall working area off NW Svalbard in the Fram Strait (squares). Cruise CAGE_14-5JM started from Longyearbyen (LYR), Svalbard on 07-10-2014 and finished in Longyearbyen on 17-10-2014. Seismic lines (black), CTD stations (black dots), and gravity cores (GC) are marked. P numbers represent locations of the theoretical gas hydrate stability outcrop zone. Only P14 showed gas flare activity on the Yermak Plateau.

1 Summary

CAGE_14-5JM cruise allowed to study the gas release from gas hydrated sub-seabed environments at the continental margin off NW and N-Svalbard and the transport and distribution of methane within the water column. We carried out acoustic profiling (18, 38 and 120 kHz) in the water column, CTD water sampling for gas analyses, seismic profiling (mini GI guns), bathymetry mapping (EM300), and sediment gravity coring (3m corer) (Fig. 1a, b). Though water above gas flares may be enriched in methane, methanotrophic microbes can reduce the methane concentrations and thus the amount of methane that may escape from the seabed to the ocean, one of the topics investigated during this cruise.

2 Participants and Affiliations

2.1 Participants

1.	Jürgen Mienert	Chief scientist	UiT_CAGE
2.	Andreia Plaza Faverola	Seismics	UiT_CAGE
3.	Kate Alyse Waghorn	Seismics	UiT_CAGE
4.	Westvig Ingvild Myrvang	Seismics	UiT_CAGE
5.	Aleksei Portnov	Seismics	UiT_CAGE
6.	Petter Andreas Lundekam	Tectonics	UiT
7.	Giacomo Osti	Sedimentology	UiT_CAGE
8.	Joel Johnson	Sedimentology	UNH; USA
9.	Weil-Li Hong	Sediment Geochemistry	UiT_CAGE
10.	Friederike Marie Luise Gründger	Sediment Geochemistry	UiT_CAGE
11.	Giuliana Panieri	Micropalaeontology	UiT_CAGE
12.	Katia Carbonara	Micropalaeontology	Uni_Parma
13.	Pår Jansson	Oceanography	UiT_CAGE
14.	Steinar Iversen	Engineer	UiT
15.	Annop Nair	Engineer	UiT_CAGE
16.	Pauls Dubourg	Fisheries	UiT_NFH

2.2 Affiliations

UiT_CAGE	UiT The Arctic University of Norway, Tromsø CAGE - Centre of Arctic Gas Hydrate, Environment and Climate
UNH	University of New Hampshire, Dept. of Earth Sciences 56 College Rd. Durham, NH USA
Uni Parma	University of Parma, Italy

3 Research program

3.1 Introduction

Gas hydrates form ice-like crystals occurring in the pore space of sediments in continental margins at high pressure and low temperature. Gas hydrates consists mainly of methane and water and therefore is often called methane hydrate. Methane hydrates may also form in pan-arctic permafrost areas from land to ocean (Sloan Jr., 1998). The stability of both hydrates in continental margins and permafrost is mainly governed by temperature variations. Hence, hydrate stability will be affected by future warming of the Earth's ocean and land masses.

Large uncertainties exist when estimating the total amount of carbon stored in gas hydrates and the free gas reservoirs beneath it. Values for gas hydrates range from 500 to 5000 Gt of carbon (e.g. Buffett and Archer, 2004; Milkov, 2004; Kvenvolden & Rogers, 2005) but free gas reservoirs may add approximately 1800 Gt of organic carbon (Buffett and Archer, 2004). The total carbon reservoirs are enormous and comprise almost half of the Earth's organic carbon. If these carbon stores entered the atmosphere, they would affect climate – leading to a greenhouse world'

The long- and short-term dynamics of this carbon reservoir need to be better understood. One could envision a rapid release of methane that would have recognisable effects on climate as most of this methane (as carbon) is a 25-35% more effective greenhouse gas than CO_2 (Harvey and Huang, 1995; Shindell et al., 2009). A change in ocean temperature of 3°C would for example release globally ~4000 Gt of carbon into the ocean and atmosphere, but again large uncertainties from 500 (Biastoch et al., 2011) – 4000 Gt (Archer and Buffett, 2005) exists regarding such predictions.

Climate models do not yet include the dynamical behaviour of carbon flux rates from the seafloor via the water column above to the atmosphere. Models assume that the present amounts of released carbon from the seafloor are small. The assumption is based on a situation where carbon does not reach the atmosphere as methane gets oxidised in the water column. However, more evidence accumulates that even at the present time there are significant variations and the amount of methane venting from the seabed through shallow seas of large Arctic shelf regions may become larger (Shakova et al.; Portnov et al. 2013). Evidence exists also from deep water areas from which methane may reach the atmosphere (Dimitrov, 2002; Kennett et al., 2003; Kastner et al., 2005, Smith et al., 2013).

Triggering of submarine landslides on glaciated continental margins may be at least partly related to dissociation of gas hydrate and migrating fluids leading to overpressure build up (e.g. Mienert et al., 2005; Mienert, 2009). The part of the gas hydrate system that is most strongly affected by bottom-water warming is the zone where the base of the gas hydrate stability zone (BGHSZ) intersects the seabed, which is at the most upper continental margin (Jung and Vogt, 2004; Mienert et al., 2005). In the Arctic this zone is at approximately 350 m water depth. Because most, if not all, of the investigated submarine slides are retrogressive (Solheim et al., 2005; Vanneste et al., 2006; Hogan et al., 2013) the instability starts at the toe and not at the upper end of the slope. However, gas hydrate dissociation triggered by ocean warming would start at the top of the slope leading most likely to a progressive and not a retrogressive slope failure.

The Centre of Excellence CAGE – Centre for Arctic Gas Hydrate, Environment and Climate aims to understand how the gas hydrate reservoirs and methane production and uptake systems will react to future increases in bottom-water temperature. Future bottom-water warming might trigger a sudden release of large amounts of methane leading to changes in the ocean environment and climate.

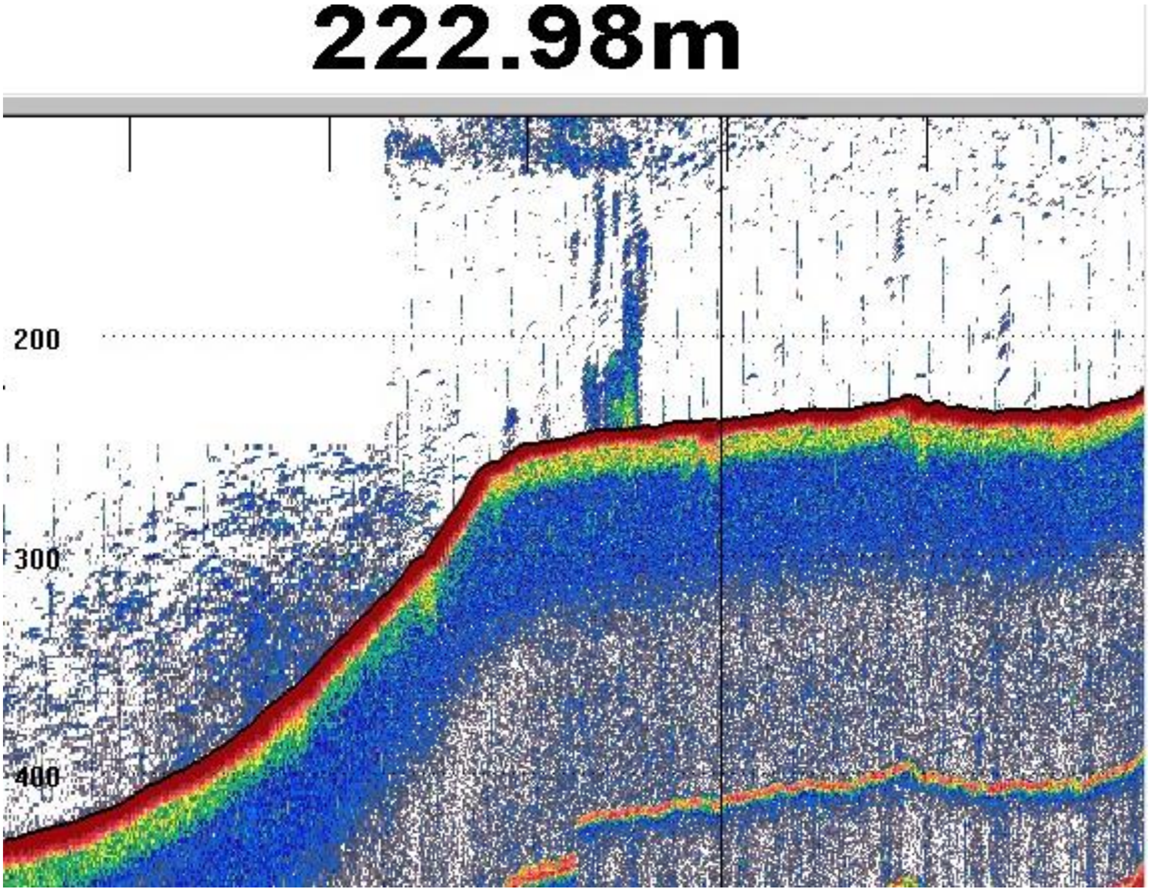

Fig. 2: Gas flares at the outer shelf off Prins-Karls Forland. Evidence for numerous flares seems to be confined to a narrow bathymetric interval coinciding with the theoretical feather edge (Ruppel, 2011) of the gas hydrate stability zone (GHSZ) at ~240 m (Westbrook, et al. 2009; Rajan et al., 2012).

3.2 Cruise activities

The main activities during the cruise included:

- CTD stations transect from the shelf at 70 m water depth to the slope at 1360 m water depth for measurements of ocean water masses, water mass sampling for water/gas chemistry across methane seeps.

- Gravity and multicorer sampling for studying sediment surface and shallow sediments with respect to microbiology and geochemistry. Core locations are along the CTD transect from the shelf at 70 m water depth to the slope at 1360 m water depth. 24 stations of up to 3 m long cores have been carried out.

- 18 and 38 kHz single echo sounder profiling for gas bubble detection and release mapping. This study also allows to locate the best locations for seabed observatories. The multi-frequency echosounder allows flare imaging, which in turn helps to identify active seeps and variations in their activity.

- Gravity coring for studying the age of sediment mass movement events along eastern Fram Strait.

- Subsampling of gravity corer and multicorer for investigating foraminifera, ostracods and coccolitophorids. Core locations are along the CTD transect from the shelf at 70 m water depth to the slope at 1360 m water depth.

- Gravity core sub-samples along the CTD depth transect for detailed geochemical and microbiological analysis to investigate the microbial communities responsible for organic matter degradation, and the generation and consumption of methane in sediments of the Arctic.

- Subsampling of the gravity cores GC-01 through GC 12 was completed for TOC, $CaCO_3$, TS, TN, and grain size analyses on board. These measurements will help to characterize down core variations in detrital and diagenetic products within the sediments from methane and non-methane rich core sites.

- All gravity cores collected during the cruise were logged using the multi-sensor core logger to determine down-core variations in magnetic susceptibility and bulk density. Cores with depleted magnetic susceptibility will be investigated further to decouple methane-related diagenesis from detrital signatures in the recovered core stratigraphy.

3.3 Deviations from the intended cruise schedule

The cruise followed the intended cruise schedule as planned because the weather has been on our side with a calm sea.

3.4 Compliance with the regulations for responsible marine research

We complied with the regulations for responsible marine research. The cruise activities were outside of the Svalbard National Park boundaries. During the cruise the ship was operated in clean ship mode except for disposal of sediments after sampling.

3.5. Water mass and pore-water sampling

CTD - Water Mass Analyzes Pår Jansson

We took 265 water samples (100ml bottles) from 24 CTD-stations throughout the cruise. The water samples will be analyzed for dissolved methane at the Department of Biology at the University of Tromsø or at the “GEOMAR Helmholtz-Zentrum für

Ozeanforschung" in Kiel, Germany. To stop bacterial activity that would distort the measurements, water samples were poisoned immediately after sampling. Because the use of mercury-chloride is prohibited on Norwegian research vessels, this was done using 1 ml saturated NaOH solution. We took between 6 and 12 water samples at different depths per CTD station. One sample was always taken at 10m depth below sea surface and one 10m above seabed. The remaining 10 samples were taken at different depth intervals in-between. The vertical distance between the samples was smaller closer to the sea bottom, because we expected more variations in dissolved methane concentration here.

We also took 265 20 ml water samples for the purpose of analyzing nutrient concentrations. These samples were poisoned with 0.2 ml of chloroform to stop biological activity. These samples will be analyzed at the Institute of Marine Research in Bergen.

CTD Number	Station Nr.	Position Longitude/Latitude	Number of Bottles
CTD_CAGE_14_5JM_1	650		6 (GOpro cam)
CTD_CAGE_14_5JM_2	651		7
CTD_CAGE_14_5JM_3	652		11
CTD_CAGE_14_5JM_4	653		12
CTD_CAGE_14_5JM_5	654		12
CTD_CAGE_14_5JM_6	655		12(GOpro cam)
CTD_CAGE_14_5JM_7	656		12
CTD_CAGE_14_5JM_8	657		12
CTD_CAGE_14_5JM_9	658		12
CTD_CAGE_14_5JM_10	659		12
CTD_CAGE_14_5JM_11	660		10
CTD_CAGE_14_5JM_12	661		10
CTD_CAGE_14_5JM_13	662		10
CTD_CAGE_14_5JM_14	663		11
CTD_CAGE_14_5JM_15	664		11
CTD_CAGE_14_5JM_16	665		11
CTD_CAGE_14_5JM_17	666		12
CTD_CAGE_14_5JM_18	667		12
CTD_CAGE_14_5JM_19	668		11
CTD_CAGE_14_5JM_20	669		12
CTD_CAGE_14_5JM_21	670		12
CTD_CAGE_14_5JM_22	671		12
CTD_CAGE_14_5JM_23	672		12
CTD_CAGE_14_5JM_24	673		12
CTD_CAGE_14_5JM_25	674		12

Table 1. CTD number and corresponding station numbers. See appendix 2 for CTD CTD locations and profiles.

Multi-Sensor-Core Logging (Joel Johnson, Giacomo Osti)
All gravity cores were logged from this cruise at sea, onboard the Helmer Hanssen. The MSCL core logger collected magnetic susceptibilty and bulk density data. Gravity cores GC-07 through GC-12, GC-21, and GC-23 through GC-28 had pore

water samples removed prior to logging on the MSCL, thus the bulk density is a bit compromised (see the porewater sample log for the volume of pore water removed and sample intervals). Gravity cores GC-13 through GC-20 were not sampled for pore waters, thus the bulk density is correct. GC-23 interval 100-122 cm (sec. 8 in data file) was missing at the time of logging, so a spacer was used in this interval, as if it were sampled. This missing section needs to be logged and integrated with the rest of the core. All recorded depths are measured on the MSCL and included errors associated with mis-fit end caps. Thus total logged core lengths may differ from labeled section lengths.

Gravity cores GC-07 through GC-12 were collected from potential methane-bearing sites upslope of Vestnesa Ridge. All of these cores were sampled for pore water, microbiology, foraminifera, CHNS, and grains size measurements for paleo-methane flux studies. Gravity cores GC-21 through GC-28 were also collected in the vicinity of Vestnesa Ridge for paleo-methane flux studies. Gravity core GC-28 was a reference site and the magnetic susceptibility and density records document a thick (~2 m) graded sequence (slope failure deposit) that dominates the record. From these records cores GC-11 and GC 12 smelled of H2S and have the best potential for paleo-SMT studies. Gravity cores GC-13 through GC-20 were collected from the Spitsbergen Fault Zone Slide Complex and were collected for stratigraphic studies. These cores were only sampled at sea for a calcareous nannofossil study.

Biogeochemistry and Geomicrobiology (Friederike Gründger, Wei-Li Hong)

The biogeochemical and geomicrobiological characteristics of sediments in Svalbard's Arctic margins are largely unknown Knowledge on biogeochemistry and geomicrobiology can help to understand the driving processes linked to origin and fate of gas that migrates from deep to shallow sediment layers. We do a detailed geochemical and microbiological characterisation of sediments to investigate the methane consumption potential of indigenous microbial communities. We investigate the microbial communities responsible for organic matter degradation, and the generation and consumption of methane. We will identify the particular ecosystem structure and function of the microbial populations across vertical (depth profiles of sediment cores) and horizontal (sampling sites around cold seeps with varying methane fluxes) gradients. We determine the microbial communities in the aerobic sediment (top layer), the sulfate methane transition zone (SMTZ) and anaerobic sediment layer possibly associated with CH_4 hydrates.

We integrate geochemical and microbiological data from sediment and pore water analyses to characterize the different sedimentary environments above the methane hydrate stability zone and at the feather edge of the hydrates on the upper continental slope.

Sampling and analyses:

We sampled the gravity cores CAGE-GC3, -07, -11, -12 along a CTD transect (Figure 1a, b), CAGE-GC24, -25 located at the Vestnesa ridge, as well as CAGE-GC26 and -27 located east of the Vestnesa ridge for microbiological investigations. All cores were sampled in 30 cm intervals from top to bottom. Sediment samples have been taken for fluorescence *in situ* hybridization (2 x 0.5ml). Microorganisms in sediment were fixed with 2% formaldehyde solution immediately, washed twice with phosphate buffer and stored at -20 ^oC in a ethanol-phosphate solution (1:1). Furthermore, sediment samples for DNA and RNA analyses (50ml) stored at -80 ^oC, microbiological cultivations and enrichments (~100ml) stored at 4 ^oC and geochemical analyses (~50ml) were collected. Additionally, for quantitative and qualitative analyses of microorganism in the water column, deep water samples (~2 L) have been taken from CTD positions 660, 673, and 675 and stored at 4 ^oC.

A total of 134 pore water samples from 13 sites were collected (GC-07, 08, 09, 10, 11, 12, 21, 23, 24, 25, 26, 27, 28). Porewater was extracted by Rhizon under cold temperature (lower than 4 ^oC). For each of the sample, depending on the amount of pore water extracted, the water sample was distributed for the analyses of carbon isotope of dissolved inorganic carbon (DIC), concentration of DIC, chlorinity, sulfate content, concentration of nutrients, and concentration of cation species. To best preserve each of the sub-samples for future analyses, various treatments were done. The water samples for DIC isotope and concentration were poisoned with $HgCl_2$ to terminate any microbial activity. 0.1 ml of zinc acetate was added to all the water samples for sulfate concentration analyses to prevent re-dissolution of H_2S gas. Water samples for cation were stored in acid-washed Nelgen bottles. Water samples for nutrient were frozen in -20 ^oC freezer immediately after sampling. All water samples, except for the samples for nutrient, were stored in 4 ^oC fridge. The analyses of these items will be done in collaboration with others.

Sediment and porewater samples for geochemical analyses are taken in short intervals (30 cm) from the sediment cores. Analyses can be categorized as cations, anions, nutrients, stable isotope of carbon species, and hydrocarbon gases (C1 to C3). Proper subsampling and preservation of samples will be done onboard and analyses afterwards at onshore laboratory at UiT. For cation species, we measure elements such as calcium and magnesium, which are essential to estimate saturation of carbonate minerals in the pore water. Metal species, such as iron and manganese, will be measured as they are part of the redox chain in marine sediments. For anion species, we measure sulfate, chloride, and dissolved inorganic carbon (DIC). Chloride profiles will be used to detect if there is any dissociation of gas hydrate as well as input of deep fluids, which may be fresher than seawater due to clay mineral dehydration. Sulfate and DIC are essential for the discussion of various biogeochemical reactions. The results are important for microbiology studies. For the nutrient species, we measure dissolved ammonium, phosphate, and silicate. These nutrient species will be used to constrain the rate of organic matter degradation within both sulfate reduction and methanogenesis zones. For the isotope of carbon species, we measure carbon isotopes of both methane and DIC. The isotopic profiles of these two species will help define hotspots of microbial activities. Samples for determining concentration of hydrocarbon gases will be collected. The information, together with isotopic signatures of methane, will be used to discuss the origin of hydrocarbon gases.

Microbiological samples for quantifying microbial activities and communities come from the same depth interval as geochemistry samples. Sediment microcosms is set-up to measure metabolic rates of important microbial processes, i.e. sulfate reduction, methane and carbon dioxide formation and consumption. We will use different cultivation techniques, gas chromatography and photometric analyses. Samples for molecular biological studies of the quantitative and qualitative microbial community composition will be collected, partially fixed for fluorescence-in-situ hybridisation (FISH) and stored frozen for onshore analyses.

Core-Number	Station Nr	Position Longitude	 Latitude	Number of Samples
CAGE-GC01	847			4
CAGE-GC02	848			4
CAGE-GC03	849			6
CAGE-GC04	850			3
CAGE-GC05	851			6
CAGE-GC06	852			5
CAGE-GC07	853			
CAGE-GC08	854			
CAGE-GC09	855			
CAGE-GC10	856			
CAGE-GC11	857			
CAGE-GC12	858			
CAGE-GC13	859			
CAGE-GC14	860			
CAGE-GC15	861			
CAGE-GC16	862			
CAGE-GC17	863			
CAGE-GC18	864			
CAGE-GC19	865			
CAGE-GC20	866			
CAGE-GC21	867			
CAGE-GC22	868			
CAGE-GC23	869			
CAGE-GC24	870			
CAGE-GC25	871			
CAGE-GC26	872			
CAGE-GC27	873			

Table 2. Pore-water analyzes from gravity cores (Friederike Gründger, Wei-Li Hong), core numbers and corresponding station numbers. See appendix 2 for core locations and table or sediment recovery and sampling procedure.

Coccolithophorida in Arctic waters of rising temperature (Katia Carbonara, Giuliana Panieri)

The coccolithophores are calcyfing protists that have formed a significant part of the oceanic phytoplankton since the Jurassic, ~150 million years ago. Their role in regulating the Earth system is considerable. Ocean water masses and coccolithophores play a role in the uptake of CO2 and transport of CO2 via fecal pellets to the abyss of the ocean (Schlüter et al., 2013). Through their secretion of a tiny composite exoskeleton (the *coccosphere*, made of multiple *coccoliths*), the coccolithophores are estimated to be responsible for about half of all modern precipitation $CaCO_3$ in the oceans (Milliman, 1993). Formally coccolithophores are separated from other phytoplankton such as diatoms by the presence of a third flagella-like appendage called haptonema, althought the flagella bearing stage is often only one of a multi-stage life cycle.

A coccolith is a single disc-like plate which is secreted by algal organism (Haptophytae), varying shaped plates. On death, the individual coccoliths invariably become separated and they are most commonly preserved in the sedimentary record. Occasionally complete coccospheres are preserved and provide valuable information.

Preparation technique- smear slides: the extreme small size (smaller than 30 µm) of nannoplankton implies that a very tiny amount of sediment is required. Due to the small size of fossils, the chance of contamination is higher than for other microfossils. The preparation of the smear slides for light microscopic examination followed the procedures described by Haq & Lohmann (1976), Backman & Shackleton (1989) and Bown & Young (1998).

1, Scrape a small portion of sediment onto a cover slip;
2, Add a drop of distilled water and make a sediment suspension, using a wooden toothpick;
3, Smear the suspension thinly across the surface of the cover slip with the toothpick and dry on a hotplate;
4, Label a glass microscope slide and glued the cover slip, using Norland optical adhesive.

Total abundance and species diversity are low, as expected in Arctic setting (Baumann et al., 2000). Preservation of calcareous nannofossils is good to moderate throughout the prepared samples. *Coccolithus pelagicus* and *Emiliania huxleyi* are dominant. Some gephyrocapsids and *Calcidiscus leptoporus* are present, though rare, and they may be indicative of different water mass influence. Samples from GC 03 appear barren, due to the sand fraction (Table…). Some coccospheres are observed in GC 12 samples (Table) and it might indicate rapid burial or high sedimentation rate.

Seismic survey (Andreia Plaza Faverola, Kate Alyse Waghorn, Westvig Ingvild Myrvang)

Single Beam Survey over seep area to select ocean observatory locations (Andreia Plaza Facerola, Pår Jansson, Alexey Portnov)

Seep areas may become active or inactive for yet unknown reasons. The seep area west of Prins Karls Foreland has been subject of repetitive single beam surveys by the University of Tromso during the last years. Due to the high change in acoustic impedance, hydro acoustic systems are very sensitive to gas bubbles in the water column. This makes single beam echo sounders an effective tool to investigate gas bubble releases in the water column. Data gained, allows the imaging of methane bubble flares in the area and can further be used for methane flux estimations.

During this survey a calibrated Kongsberg EK60 multi-frequency echo sounder was used. The system can operate parallel in three different frequencies (18 kHz, 38 kHz and 120 kHz), but due to technical difficulties only the 18 kHz and the 38 kHz signal were used.

The investigated seep area is divided into two areas. One deeper area between 400m and 350m- and a shallower one in about 250m water depth. For a complete mapping of the area the footprint of the single beam system at the different water depth has to be considered and the survey lines must be planned accordingly. During this cruise we repeated the survey of the last investigation of the seep area from 2012. For high quality imaging and later flux estimations a high spatial resolution (ship along track) is important. To archive this, the maximum ping rate available was used and the ships speed was reduced to 5 knots during the survey. A speed of only 3 knots or less would have been even more optimal, but was not possible due to the limited time planned for this survey.

The data was loaded into FMMidwater tools for quick analyzes of the flares positions. Later post processing analyzes will allow estimations of the gas flux in the seep area that can be compared to the data of previous Helmer Hanssen surveys of UiT The Arctic University of Norway.

Ocean current velocities (Pår Jansson)
Ocean current velocity measurements come from the vessel mounted ADCP (Acoustic Doppler Current Profiler). A RD Ocean Surveyor operates at in broadband mode at 75 kHZ. The instrument relies on the doppler shift in the backscattered sound pulse emitted from four transducers mounted on the lowered keel of the vessel.
We installed new software from Aqua Vision, which requires the user to plug in a USB license dongle. The software records raw data and simultaneously displays currents and other related information in real time, much like a traditional echosounder. The ADCP was set up using bin sizes of 16 meters or more depending on water depth. Large bin sizes are necessary because the Arctic water is relatively clear (containing few particles for the sound to scatter on). To view the currents in real time in shallow water the "Mark BBB" was switched on and in deep water it is necessary to switch it off.

Communication settings required for the software to run onboard Helmer Hanssen with the existing ADCP-computer setup;

Device	Port	Baudrate	Parity	Data bits	Stop bits
ADCP	COM5	9600	No	8	1
NAV	COM2	19200	No	8	1
GYRO	COM1	19200	No	8	1

4 Cruise narrative

Tuesday 07.10.2014
On 07.10.2014 we left Longyearbyen at 20:00 GMT heading northwest towards Prins Karls Forland. Echosounder and multibeam profiling took place while on route to the first area, which we reached at 09:00 GMT on Wednesday morning.

Wednesday 08.10.2014
We started with CTD stations (stnr 650-674) including water mass sampling for gas analysis with a max. of 12 and a minimum of 6 bottles at prescribed intervals. In between CTD stations we used single echosounder profiles (38 and 18 kHz) from the shallowest station at 74 m to the deepest station at 1360 m water depth.

Thursday 09.10.2014
We finished the last CTD station (stnr 674) successfully at ~ 06:31 GMT.

Afterwards, P-Cable streamer sections were connected (4 sections, each with a length of 25 metres and with 8 channels) allowing for a total streamer length of 100 m and 32 channels. Mini GI guns (15/15 and 30/30) were rigged up to start seismic profiling together with echosounder (18, 38, 128 kHz) and multibeam profiling along the CTD transect (stnr 650-674). Line 01started at 09:30 GMT (Line 01) at 1605 m water depth (78^{o} 36.160N; 10^{o} 8.470E), continued with line 02 – and 03 in the same direction (NW) and finally ended Line with 04 at 22:45 at ~100m water depth at the headwall of a slide at the slide complex .

During the night, we repeated echosounder profiles at a speed of 5 kn across flares. They have been mapped in previous years and we use the same parameters and frequencies, i.e. 18, 38 and 128 kHz. Multibeam and chirp echosounders were turned off during flare mapping.

Friday 10.10.2014
We started gravity coring at 09:00 GMT (station 847, GC 01) and finished at 19:00 GMT (station 858, GC 12). Core location marked on the P-Cable seismic profile (Line 01), are along the seismic Line 01 and CTD stations. Inner and outer shelf sediments contain high contents of clay, sand and gravel limiting the core penetration and recovery to < 1m. Outer shelf sediments show less sand and gravel at 245 m water depth. Slope and basin sediments show basically clay and fine grained sand but no gravel in water depth > 400m. Active gas release locations were observed at the outer shelf and slope were we took sediment cores.

Sediments from cores GC10 and GC11 smelled of H_2S. Both cores came from the “mud volcano location. On the shelf, core recovery was low but on the slope and basin core recovery reached 2,5 metres using a 3 m long steel barrel. A core catcher hindered that sediments slipped out the liner. Several times we reached full penetration but never full recovery. It took us about 30 minutes to take one gravity core and about 1,5 hours to sample the core and store the sediments. Note, we used only a 3 m long steal pipe and a plastic liner inside because the large winch for heavy and long coring was broken.

Seismic Line 05 started at 21:52 and ended the next day, 11.10. 02:30 GMT.

Saturday 11.10.2014

Start of seismic line 06 was at 02:29 GMT and start of seismic line 07 at 06:31 GMT. End of line 07 was at 16:00 GMT (14:00 UTC) at the margin of the sea ice. The water temperature dropped from plus degree to minus 0.7 degrees Celcius and the air temperature to minus 6.4 ^{o} C. The low water temperature caused one mini airgun to freeze at 12:00 GMT. The problem was solved by injecting alcohol into the air pressure pipe.

We started sediment coring at 17:00 GMT at the Senja Fracture Zone (SFZ) slide complex, i.e. above glide planes. Station 859 (GC 13) to station 863 (GC 17) retrieved up to 248 cm of sediment. Sediment material looks brownish without a smell of methane or H_2S. The coring finished at~24:00 GMT.

Note: Sea ice surrounded RV Helmer Hanssen at 79^{o} 49.848N, 4 ^{o} 37.821 E at 16:00 GMT, and “pancake” ice showed the process of growing new sea-ice all around us. Due to sea ice and frozen guns, we were forced to abandon seismic profiling.

Sunday 12.10.2014

We left the Spitsbergen Fracture zone during early morning hours and sailed to Kongsgrunnen, which we reached at 14:00 GMT. Echolot profiling (18, 38, 128 kHz) started along the ~300 m isobath at 14:10 GMT. Profiling lines are meant to coincide with our modelled methane hydrate stability outcrop zone along the north slope of Svalbard. Our acoustic survey concentrated on detecting flares. No flares were detected and we sailed to the start for seismic line 08, which we reached on Monday morning.

Monday 13.10.2014

Start of seismic line 08 was at 09:17 GMT, start of line 09 at 10:59 GMT and start of line 10 at 14:51 GMT. After finishing the seismic line, we took 3 more gravity cores (3m core barrel) within the SFZ slide scar area at stations 864-866 (GC18, GC19, and GC20). Afterwards, we started seismic line 11 at 19:29 GMT and line 12 at 23:58 GMT. A streamer leakage caused us to stop line 12 at 03:33 GMT on Tuesday.

Tuesday 14.10.2014

Line 13 started at 14:56 and finished at 17:09. After surveying potential BSR outcrop zones at the toe of the Vestnesa Ridge we started coring stations 867-869 (GC21, GC22, GC23). The first two cores recovered < 1m and only core GC23 was more than 2 metres long. Station 870 (GC 24) was at an inactive pockmark previously sampled and a paper is in press related to climate studies (Consolara et al., 2014). Afterwards we took CTD 674 at an active pockmark were we also took a core for microbiological studies at station 871 (GC 25). During this cruise our last core station was on the upper slope of the continental margin at station 872 (GC26), were we recovered turbidites.

Wednesday 15.10.2014

Line 14 started at 07:34 and ended at 10:38 followed by line 15 at 10:50, which ended at 12:52. We stopped the profile because of massive sea ice in front of us. Line 16 started at 15:13 GMT and ended at 18:03. Again the line was stopped because of sea ice.

Thursday 16.10.2014

Line 17 started at 04:01 GMT and ended at 07:59. Due to increasing wind speed and higher waves the recording noise increased significantly. Writing of reports and seismic data processing continued on our transit to Longyearbyen. Because the seismic line 18 and 19 noise level increased more and more due to high waves, we stopped profiling at 11:27 GMT.

We ended the research work at sailed back to Longyearbyen.

Friday 17.10.2014

FF Helmer Hanssen arrives in Longyerabyen at 0700 GMT.

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Appendixes

Expedition: Helmer Hanssen October 2014 Survey: CAGE_2014_5_JM-seis 09.10.14 – 18.10.14

Times are UTC

2D line number:	Date: Start - end	Time (UTC): Start - end	Shot point number First - last	Comments (sailing direction, ship speed, depth sensor, wind speed, air temperature downtime, etc.)

Always make sure GPS (GPGGA string) is captured and "Time stamp changed to GPS time"
Always make sure navigation (seatrack data) is captured for each line separately in PCOMM Terminal

General survey parameters:
100 m, 32 channel solid state streamer (33 m behind vessel and 15 m across offset from the gun float; geometry parameters relate to gun position, which is captured on Seatrack)

Ship's speed: 4.2 - 5 kn
Gun system: 2 x mini-GI (15/15 in3) & (30/30 in3)

at 1.75 m water depth

33 m behind ship
Shooting pressure: ~160-170 bar

2D line number:	Date: Start - end	Time (UTC): Start - end	Shot point number First - last	Comments (sailing direction, ship speed, depth sensor, wind speed, air temperature downtime, etc.)
Line 01	09.10. –09.10	07:30 - 14:06	1-4715	(Note: there is a folder named 000 with some shots named with a letter a that could be added to the beginning of the line during processing) Speed – 4.2 Kn Wind speed – 9 m/s
Line 02	9.10-9.10	14:23 – 16:56	4738-6563	Speed 4 knt *Channel 24 experience spikes now and then, but not for all shotpoints* Wind speed 11.54 m/s
Line 03	9.10-9.10	17:03 -19.55	6564-8627	Speed 4-4.5 knt Wind speed 7-8 m/s
Line 04	9.10-9.10	19.59-20.43	8628-9161	Speed 4-4.6 knt Wind speed 9-10.5 m/s
Line 05	10.10-11.10	19:52-00:27	47-3344	Speed4.4 knt Wind speed 3.5 m/s Seatrack failure 23:41 to 23:47
Line 06	11.10-11.10	00:29-	3358-5558	Shots 3345-3357 should be disregarded Sampling rate set to 0.5 to achieve 3.99s record length and 1s record delay Speed 3.3-4.5knts wind speed 12m/s0 *Shot 5483 the shotrate was changed from 10s to 6 s* *From sp 5535 rec length changed to 4.5*

2D line number:	**Date:** **Start - end**	**Time (UTC):** **Start - end**	**Shot point number** **First - last**	**Comments** **(sailing direction, ship speed, depth sensor, wind speed, air temperature downtime, etc.)**
Line 07	11.10-11.10	06:31-14:00	5559-10033	*Chan 31-32, 16 noise and bad traces.* *Channel 24 experience spikes now and then, but not for all shotpoints* Shooting rate: 6 s. Sampling rate 0.5 ms Trace length 4.5 s Delay 1 s One gun down (frozen ?) from before shot 7570 to ~shot 7769. Seatrack failed from 10:33 to 11:07 (SP 7950-8300) Gun nr.2 down from shot 9215 – 9230
Line Test	12.10-12.10	04:34-	10237-	Testing system after failures. *System accepts delay + rec length no greater than 0.16s less than shot rate… so if shot rate is 6s, delay + rec length can be 5.84* 11232 guns up on deck to defreeze. Shot 11243 gun in water shooting.
Line 08	13.10	07.17-08:04	15-582	Shooting rate 5 s Sampling rate 0.25 ms Trace length 4 s Delay 0 s We stopped the line to change batteries of the GPS Guns configured as: largest volume towards the ship (processing of the data shows that this is not an optimal configuration, two frequency picks appear one at ~80 Hz (large gun) and one at ~180 (smaller gun?)
Line 09	13.10-13.10	08.59-11:17	1-1664	Start of line, continuation of line 8 but named differently. Seatrack failed from 10:53 to 11:00 (SP 1370?-8300) We stopped line to change the position of the guns back to how it was for lines 1-7 (larger gun offshore).

2D line number:	Date: Start - end	Time (UTC): Start - end	Shot point number First - last	Comments (sailing direction, ship speed, depth sensor, wind speed, air temperature downtime, etc.)
Line 10	13.10-13.10	12:51-17:26	1665-4958	Shooting rate 5 s Sampling rate 0.25 ms Trace length 4 s Delay 0 s
Line 11	13.10-13.10	17:29-18:55	4959-5834	Shooting rate 6 s Sampling rate 0.5 ms Trace length 5.8 s Delay 0 s We stopped the line because of full leakage in streamers.
Line 12	13.10-13.10	21:58-01:33	5835-8012	Shooting rate 6 s Sampling rate 0.5 ms Trace length 5.8 s Delay 0 s *Streamer tow point is on the port side of ship.* Seatrack lost from 23:35-23:40 Gun 2 failing 00:28 shot ~7345-7443, 7513-end of line Anoop tried for a long time to defrost gun 2, but was refreezing within 5 minutes each time, so we made the decision to continue line with 1 gun. Gun 2 sometimes worked and sometimes did not.

Line 13	14.10-14.10	12:56-15:09	1-1197	Line towards Vestnesa, started a few miles south from SFZ slide Shooting rate 6 s Sampling rate 0.5 ms Trace length 5.8 s Delay 0 s *Streamer tow point is on the port side of ship on extended boom* Speed 4.3 knots Wind speed 2 m/s

				Seatemp -1.3 Airtemp -9.9 Channel 16 are dead. Shooting rate changed to 7 s at SP 399 and trace length 6.8 s at sp 405 to record deeper… Gun starts to be down, strong noisy traces from SP 1073
Line 14	15.10-15.10	05:34-08:38	1198-2774	Shooting rate 7 s Sampling rate 0.5 ms Trace length 6.8 s Delay 0 s *Streamer tow point is on the port side of ship on extended boom.* Speed 4.3 knots Wind speed 6.7 m/s Seatemp 5.1 Airtemp -4.6
Line 15	15.10-15.10	08:50-10:52	1-1041	Shooting rate 7 s Sampling rate 0.5 ms Trace length 6.8 s Delay 0 s Streamer tow point is on the port side of ship on extended boom. Speed 4.3 knots Wind speed 6.2 m/s Seatemp 2.4 Airtemp -3.6 We stoped the line because of a massive sea ice.
Line 16	15.10-15.10	13:13-16:03	*1-1455*	*Shooting rate 7 s* *Sampling rate 0.5 ms* *Trace length 6.8 s* *Delay 0 s* *Streamer tow point is on the port side of ship on extended boom.* *Speed 4.3 knots*

				Wind speed 6.2 m/s *Seatemp 2.4* *Airtemp -3.6* *We stopped the line because of a massive sea ice.*
Line 17	16.10-16.10	02:01-5:59	*1456-3500*	*Shooting rate 7 s* *Sampling rate 0.5 ms* *Trace length 6.8 s* *Delay 0 s* *Streamer tow point is on the port side of ship (extended boom bended so it is laying on deck).* *Speed 4.3 knots* *Wind speed 12.8 m/s* *Seatemp 5.1* *Airtemp -3.7* *Noisy data due to waves?* *Channel 16 is (mostly) dead*
Line 18	16.10-16.10	06:01-08:03	3501-4552	Transit line between line18 and line19 Shooting rate 7 s Sampling rate 0.5 ms Trace length 6.8 s Delay 0 s *Streamer tow point is on the port side of ship (extended boom bended so it is laying on deck)* *From shot 3997 the guns started losing pressure.* Signal back into shape at ~SP 4087

Line 19	16.10-16.10	08:05-09:27	4553-	Shooting rate 7 s Sampling rate 0.5 ms Trace length 6.8 s Delay 0 s *Streamer tow point is on the port side of ship (extended boom bended so it is laying on deck)*

Appendix 1: Location of seismic profiles at the northern termination of the Knipovich and Vestnesa Ridge, the SFZ slide complex and the NW Svalbard margin. We investigated flare areas, submarine slides at the SFZ, sediment drifts and BSRs across the drift and Knipovich transform fault.

CruiseNr	Date (UTC)	Time (UTC)	StNr	StationType	Latitude	Longtitude	Depth m	Sea °C	Air °C
2014922	08.10.2014	071657	**650**	CTD-stasjonstart	7839.981798 N	01026.760162 E	70.95	4.50	-0.10
2014922	08.10.2014	072703	**650**	CTD-stasjonstopp	7839.987288 N	01026.369771 E	71.06	4.50	0.00
2014922	08.10.2014	080531	**651**	CTD-stasjonstart	7839.906353 N	01017.486689 E	80.15	4.50	-0.10
2014922	08.10.2014	082102	**651**	CTD-stasjonstopp	7839.910282 N	01017.853765 E	77.79	4.50	0.00
2014922	08.10.2014	084651	**652**	CTD-stasjonstart	7839.660232 N	01008.072094 E	145.41	4.20	0.00
2014922	08.10.2014	090722	**652**	CTD-stasjonstopp	7839.704372 N	01007.478571 E	152.19	4.40	0.20
2014922	08.10.2014	094002	**653**	CTD-stasjonstart	7839.702370 N	01003.969670 E	189.96	4.20	0.20
2014922	08.10.2014	095554	**653**	CTD-stasjonstopp	7839.838949 N	01003.764426 E	187.25	4.20	0.00
2014922	08.10.2014	101917	**654**	CTD-stasjonstart	7839.550682 N	00958.851680 E	186.57	4.20	0.00
2014922	08.10.2014	103440	**654**	CTD-stasjonstopp	7839.609704 N	00958.232437 E	183.21	4.20	0.00
2014922	08.10.2014	105901	**655**	CTD-stasjonstart	7839.580286 N	00950.660080 E	128.64	4.20	0.00
2014922	08.10.2014	111046	**655**	CTD-stasjonstopp	7839.701523 N	00950.513021 E	122.56	4.30	0.00

2014922	08.10.2014	113637	**656**	CTD-stasjon.start	7839.531466 N	00941.127796 E	162.82	4.20	-0.20
2014922	08.10.2014	115057	**656**	CTD-stasjonstopp	7839.722804 N	00941.138087 E	160.94	4.20	0.00
2014922	08.10.2014	123118	**657**	CTD-stasjonstart	7839.395080 N	00932.164582 E	224.93	4.20	-0.20
2014922	08.10.2014	124407	**657**	CTD-stasjonstopp	7839.572179 N	00932.133299 E	226.73	4.20	-0.10
2014922	08.10.2014	131042	**658**	CTD-stasjon.start	7839.288782 N	00929.006186 E	236.58	4.30	-0.10
2014922	08.10.2014	132449	**658**	CTD-stasjonstopp	7839.477109 N	00928.958597 E	240.73	4.10	-0.10
2014922	08.10.2014	135114	**659**	CTD-stasjonstart	7839.212175 N	00927.459212 E	246.22	4.20	0.00
2014922	08.10.2014	140459	**659**	CTD-stasjonstopp	7839.387759 N	00927.281104 E	247.42	4.20	0.10
2014922	08.10.2014	143121	**660**	CTD-stasjonstart	7839.252473 N	00926.009256 E	242.99	4.20	0.10
2014922	08.10.2014	144704	**660**	CTD-stasjonstopp	7839.444386 N	00925.642977 E	246.64	4.10	0.00
2014922	08.10.2014	151842	**661**	CTD-stasjonstart	7839.268847 N	00924.518255 E	257.44	4.20	0.00
2014922	08.10.2014	153409	**661**	CTD-stasjonstopp	7839.358787 N	00924.280385 E	267.53	4.20	0.00
2014922	08.10.2014	155751	**662**	CTD-stasjonstart	7839.153086 N	00923.380682 E	329.13	4.10	0.00
2014922	08.10.2014	161548	**662**	CTD-stasjonstopp	7839.333719 N	00923.465230 E	323.67	4.10	0.10
2014922	08.10.2014	164101	**663**	CTD-stasjon.start	7839.245028 N	00921.618079 E	389.55	4.00	0.20
2014922	08.10.2014	165843	**663**	CTD-stasjonstopp	7839.406835 N	00921.722581 E	394.70	4.00	0.10
20149	08.10.2	1725	**664**	CTD-stasjonstart	7839.120086 N	00920.672630 E	409.07	4.10	0.00

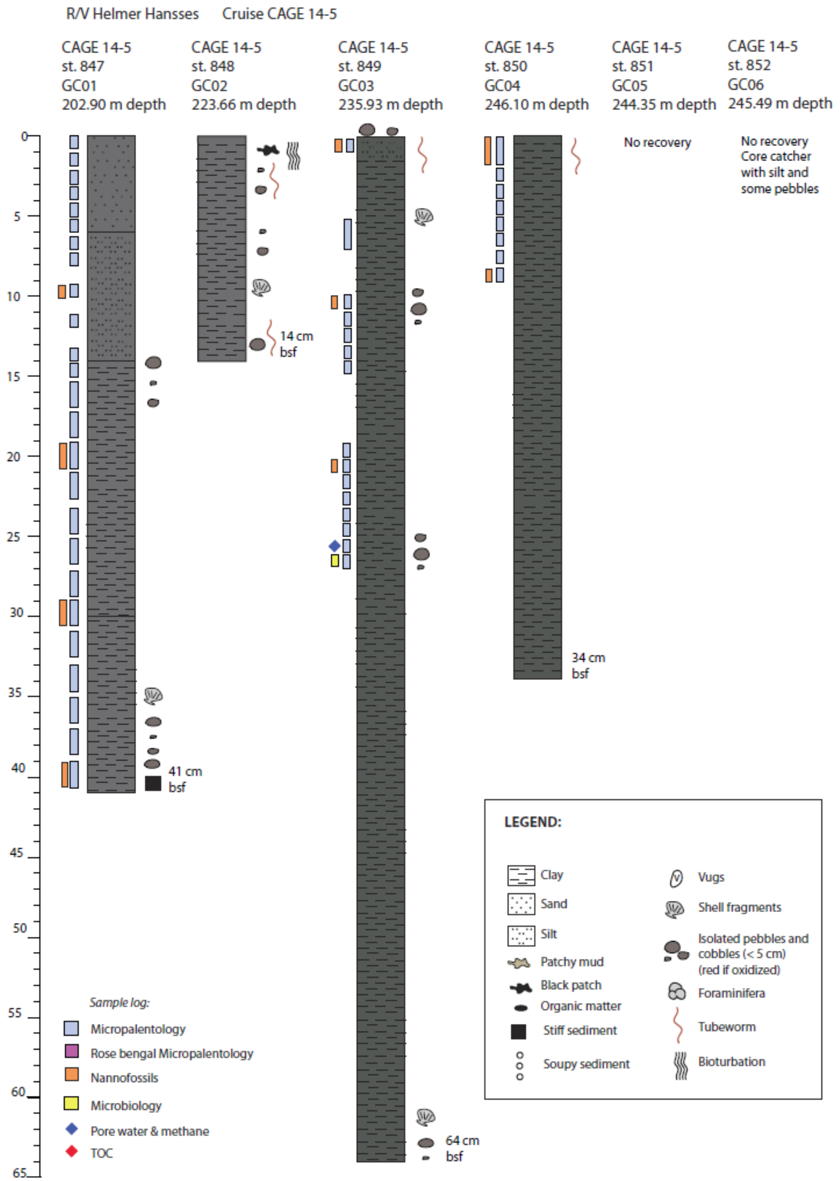
22	014	15							
20149 22	08.10.2 014	1742 39	**664**	CTD-stasjonstopp	7839.278471 N	00920.748436 E	412.20	4.10	0.20
20149 22	08.10.2 014	1823 14	**665**	CTD-stasjonstart	7838.947451 N	00917.465698 E	435.03	4.00	0.20
20149 22	08.10.2 014	1842 27	**665**	CTD-stasjonstopp	7838.974266 N	00916.240214 E	432.66	4.00	0.30
20149 22	08.10.2 014	1909 15	**666**	CTD-stasjonstart	7838.888914 N	00907.997309 E	483.59	5.40	0.50
20149 22	08.10.2 014	1930 10	**666**	CTD-stasjonstopp	7839.129831 N	00907.249239 E	488.14	5.70	0.50
20149 22	08.10.2 014	1958 04	**667**	CTD-stasjonstart	7838.638425 N	00858.315449 E	578.44	5.80	0.60
20149 22	08.10.2 014	2022 30	**667**	CTD-stasjonstopp	7838.922128 N	00857.198429 E	591.66	5.90	0.70
20149 22	08.10.2 014	2052 56	**668**	CTD-stasjonstart	7838.494865 N	00849.322508 E	658.20	5.80	0.80
20149 22	08.10.2 014	2118 52	**668**	CTD-stasjonstopp	7838.830638 N	00848.069226 E	665.03	5.90	1.10
20149 22	08.10.2 014	2146 53	**669**	CTD-stasjonstart	7838.462906 N	00839.749716 E	745.93	5.80	1.10
20149 22	08.10.2 014	2226 14	**669**	CTD-stasjonstopp	7839.089089 N	00837.894925 E	761.31	5.80	0.90
20149 22	08.10.2 014	2303 50	**670**	CTD-stasjonstart	7838.529436 N	00820.303317 E	898.17	5.50	1.10
20149 22	08.10.2 014	2340 23	**670**	CTD-stasjonstopp	7838.734097 N	00818.186502 E	901.75	5.40	1.10
20149 22	09.10.2 014	0019 41	**671**	CTD-stasjonstart	7838.206123 N	00759.762026 E	1045.36	5.20	1.60
20149 22	09.10.2 014	0106 23	**671**	CTD-stasjonstopp	7838.690871 N	00757.654324 E	1045.08	5.30	2.10
20149 22	09.10.2 014	0146 06	**672**	CTD-stasjonstart	7837.096002 N	00742.539588 E	1204.59	5.20	1.80

2014922	09.10.2014	023838	**672**	CTD-stasjonstopp	7837.677884 N	00742.549026 E	1169.19	5.10	1.90
2014922	09.10.2014	032340	**673**	CTD-stasjonstart	7836.040806 N	00724.555941 E	1487.11	4.90	2.30
2014922	09.10.2014	043125	**673**	CTD-stasjonstopp	7836.673909 N	00723.712743 E	1448.81	4.80	2.20
2014922	10.10.2014	063124	**847**	GC01	7839.252518 N	00934.191713 E	202.90	4.30	2.20
2014922	10.10.2014	073357	**848**	GC02	7839.544467 N	00933.308653 E	223.66	4.30	2.30
2014922	10.10.2014	080211	**849**	GC03	7839.220567 N	00929.111584 E	235.93	4.30	2.20
2014922	10.10.2014	083404	**850**	GC04	7839.387721 N	00925.952282 E	246.10	4.20	1.20
2014922	10.10.2014	085251	**851**	GC05	7839.324226 N	00925.991531 E	244.35	4.20	1.30
2014922	10.10.2014	091213	**852**	GC06	7839.335856 N	00925.996991 E	245.49	4.20	1.60
2014922	10.10.2014	100842	**853**	GC07	7839.330437 N	00926.015575 E	245.79	4.40	1.50
2014922	10.10.2014	104545	**854**	GC08	7839.279150 N	00925.937467 E	245.12	4.30	1.80
2014922	10.10.2014	123735	**855**	GC09	7838.020455 N	00843.294787 E	716.37	5.80	1.90
2014922	10.10.2014	141528	**856**	GC10	7837.712663 N	00827.356397 E	869.61	5.70	2.10
2014922	10.10.2014	152010	**857**	GC11	7837.708728 N	00827.454478 E	870.08	5.70	2.20
2014922	10.10.2014	170859	**858**	GC12	7837.422418 N	00742.387984 E	1185.99	5.40	2.00
2014922	11.10.2014	151551	**859**	GC13	7948.550732 N	00449.194117 E	1809.65	-0.50	-6.50
20149	11.10.2	1636	**860**	GC14	7947.576162 N	00446.686197 E	2040.34	-0.50	-6.50

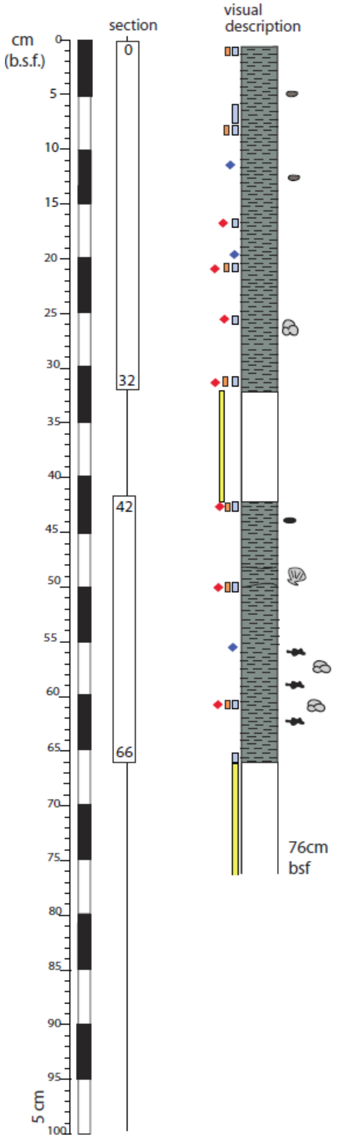
22	014	11							
20149 22	11.10.2 014	1755 09	**861**	GC15	7946.947481 N	00447.349899 E	2203.08	0.00	-5.30
20149 22	11.10.2 014	2010 52	**862**	GC16	7945.094796 N	00422.026709 E	2613.87	-1.50	-6.10
20149 22	11.10.2 014	2221 18	**863**	GC17	7944.106663 N	00432.826481 E	2709.16	-0.20	-6.00
20149 22	14.10.2 014	0404 18	**864**	GC18	7936.875830 N	00443.213176 E	2916.40	-0.90	-12.2
20149 22	14.10.2 014	0629 46	**865**	GC19	7933.924484 N	00455.304687 E	2848.33	-1.20	-9.10
20149 22	14.10.2 014	0856 14	**866**	GC20	7934.714154 N	00458.224067 E	2850.49	-0.80	-8.70
20149 22	14.10.2 014	1836 41	**867**	GC21	7913.440809 N	00433.195537 E	1650.49	-1.40	-10.2
20149 22	14.10.2 014	1944 57	**868**	GC22	7912.869442 N	00430.997697 E	1611.13	-1.50	-10.2
20149 22	14.10.2 014	2059 32	**869**	GC23	7912.211850 N	00433.286131 E	1554.21	-1.60	-8.80
20149 22	14.10.2 014	2313 11	**870**	GC24	7907.661678 N	00534.972149 E	1308.09	-1.00	-7.80
20149 22	15.10.2 014	0122 41	**674**	CTD-stasjonstart	7900.279446 N	00655.796500 E	1209.96	4.90	-5.50
20149 22	15.10.2 014	0207 11	**674**	CTD-stasjonstopp	7859.464905 N	00653.457292 E	1233.75	4.70	-5.50
20149 22	15.10.2 014	0255 26	**871**	GC25	7900.115171 N	00656.013477 E	1208.80	4.70	-5.20
20149 22	15.10.2 014	1932 21	**872**	GC26	7841.561633 N	00815.720010 E	888.28	5.70	-4.10
20149 22	15.10.2 014	2028 51	**873**	GC27	7841.375787 N	00816.617727 E	881.45	5.90	-4.10
20149 22	15.10.2 014	2132 29	**675**	CTD-stasjonstart	7841.397221 N	00816.659673 E	882.02	5.90	-4.20

20149 22	15.10.2 014	2210 44	**675**	CTD-stasjonstopp	7841.775159 N	00815.187136 E	886.02	6.00	-4.30
20149 22	15.10.2 014	2257 15	**676**	GC28	7841.562138 N	00836.987408 E	727.37	4.70	-4.50

Appendix 2: Location of CTD and core stations at the NW Svalbard margin. At the Spitsbergen Fracture Zone we mapped and cored a submarine landslide complex. At the PKF margin, the Vestnesa and Knipovich Ridge CTD stations and cores were taken at water depth up to nearly 3000 m.


R/V Helmer Hansses Cruise CAGE 14-5
CAGE 14-5 st. 847 GC01 202.90 m depth
CAGE 14-5 st. 848 GC02 223.66 m depth
CAGE 14-5 st. 849 GC03 235.93 m depth
CAGE 14-5 st. 850 GC04 246.10 m depth
CAGE 14-5 st. 851 GC05 244.35 m depth
CAGE 14-5 st. 852 GC06 245.49 m depth
No recovery
No recovery Core catcher with silt and some pebbles
41 cm bsf
14 cm bsf
64 cm bsf
34 cm bsf
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Sample log:
Micropalentology
Rose bengal Micropalentology
Nannofossils
Microbiology
Pore water & methane
TOC
LEGEND:
Clay
Sand
Silt
Patchy mud
Black patch
Organic matter
Stiff sediment
Soupy sediment
Vugs
Shell fragments
Isolated pebbles and cobbles (< 5 cm) (red if oxidized)
Foraminifera
Tubeworm
Bioturbation

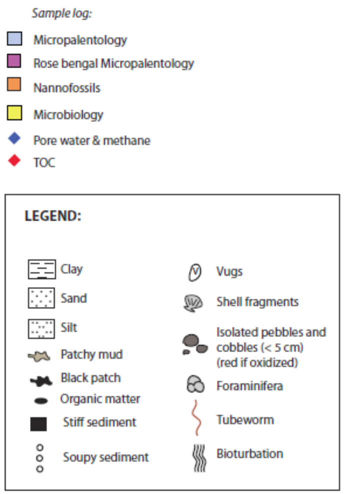
R/V Helmer Hansses **Cruise CAGE 14-5** **core GC07** **ship station 853**
Location Prins Karl Forland
Latitude 7839.330437 N **Longitude** 00926.015575 E **Water depth** 245.79 m



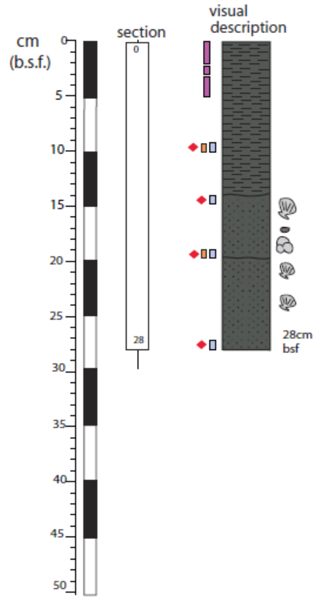
LITHOLOGIC DESCRIPTION

Major lithology: this core contains homogeneous dark gray clay. The clay is thinly laminated containing thin horizontal laminae. These sediments represent background hemipelagic depositions.

Minor lithology: Pebbles, black patches , and layers with foraminiferal shells at different intervals.



R/V Helmer Hansses **Cruise CAGE 14-5** **core GC08** **ship station 854**
Location Prins Karl Forland
Latitude 7839.279150 N **Longitude** 00925.937467 E **Water depth** 245.12 m



LITHOLOGIC DESCRIPTION

Major lithology: this core contains in the first cm homogeneous dark gray clay.
The clay is thinly laminated containing thin horizontal laminae.
These sediments represent background hemipelagic depositions.
The second half contains sil then sand with shell fragments, pebbles and foraminifera shells.

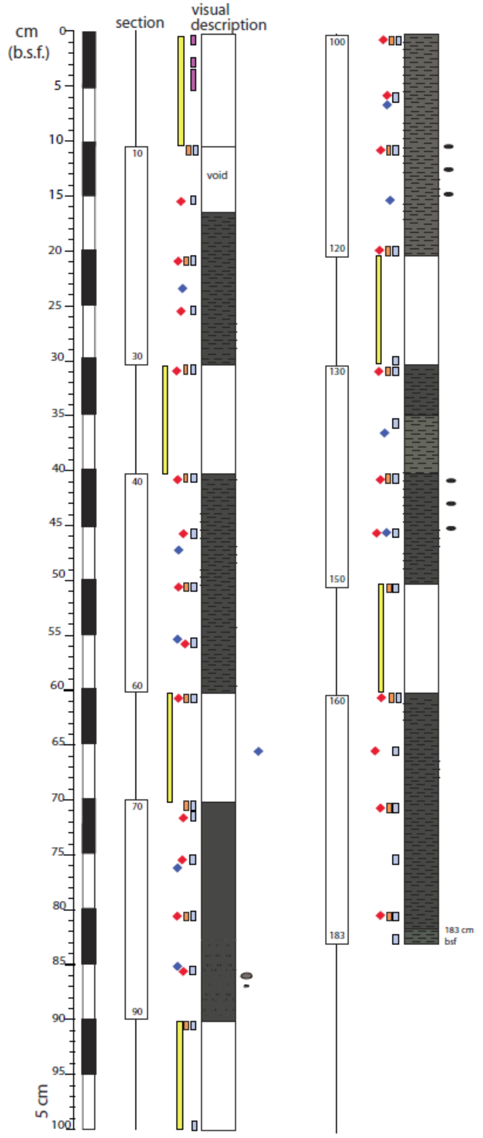
Sample log:

- Micropalentology
- Rose bengal Micropalentology
- Nannofossils
- Microbiology
- Pore water & methane
- TOC

LEGEND:

- Clay
- Sand
- Silt
- Patchy mud
- Black patch
- Organic matter
- Stiff sediment
- Soupy sediment
- Vugs
- Shell fragments
- Isolated pebbles and cobbles (< 5 cm) (red if oxidized)
- Foraminifera
- Tubeworm
- Bioturbation

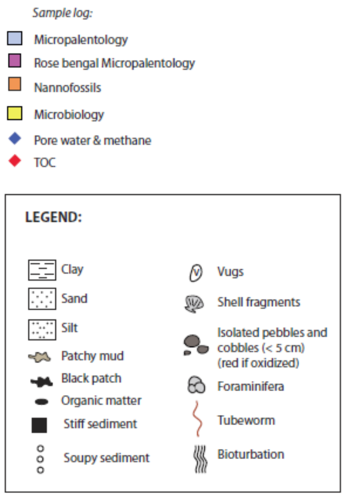
R/V Helmer Hansses **Cruise CAGE 14-5** **core GC09 ship station 855**
Location Prins Karl Forland
Latitude 7838.020455 N **Longitude** 00843.294787 E **Water depth** 716.37 m



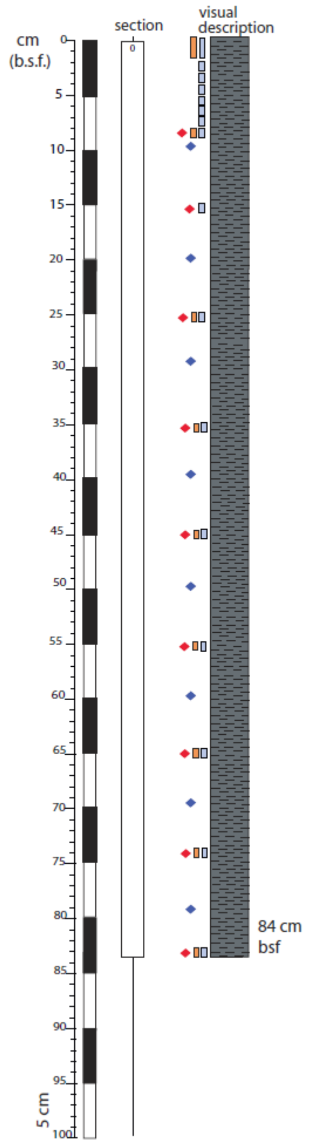
LITHOLOGIC DESCRIPTION

Major lithology: this core contains homogeneous dark gray clay. The clay is thinly laminated containing thin (<0.3 cm thick) horizontal laminae. These sediments represent background hemipelagic depositions. H2S smell during the recovery

Minor lithology:
Pebbles occurr at different intervals.
Iron sulphide patches are present.

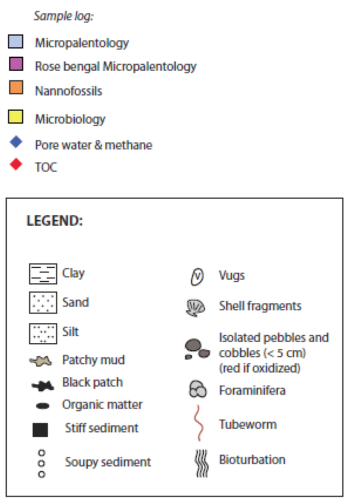


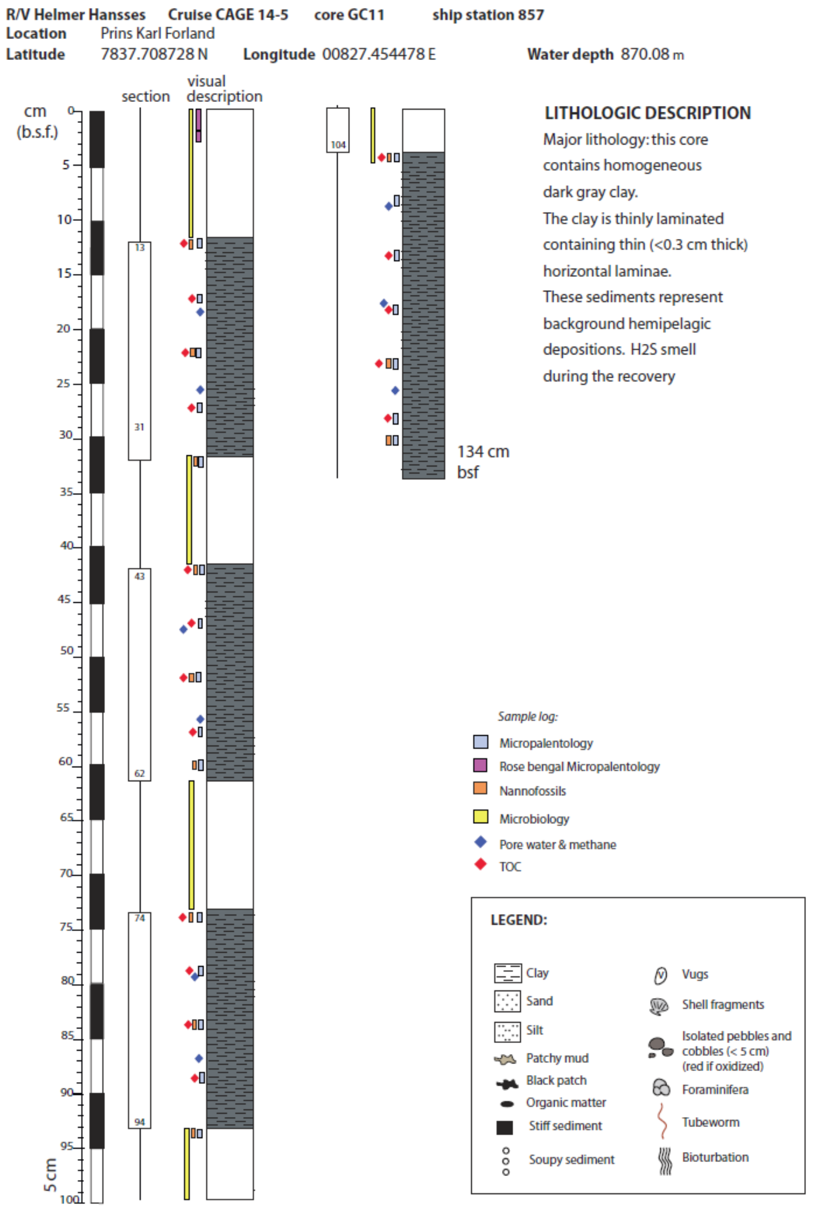
R/V Helmer Hansses **Cruise CAGE 14-5** **core GC10** **ship station 856**
Location Prins Karl Forland
Latitude 7837.712663 N **Longitude** 00827.356397 E **Water depth** 869.61 m

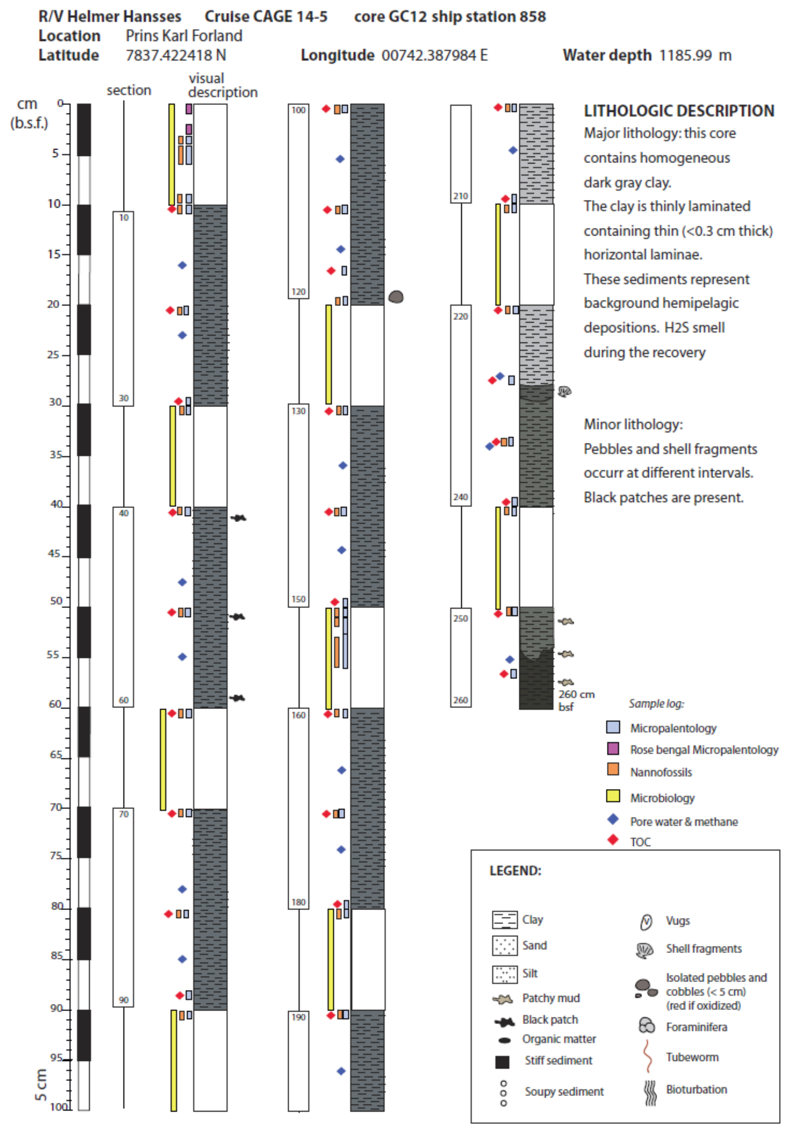


LITHOLOGIC DESCRIPTION

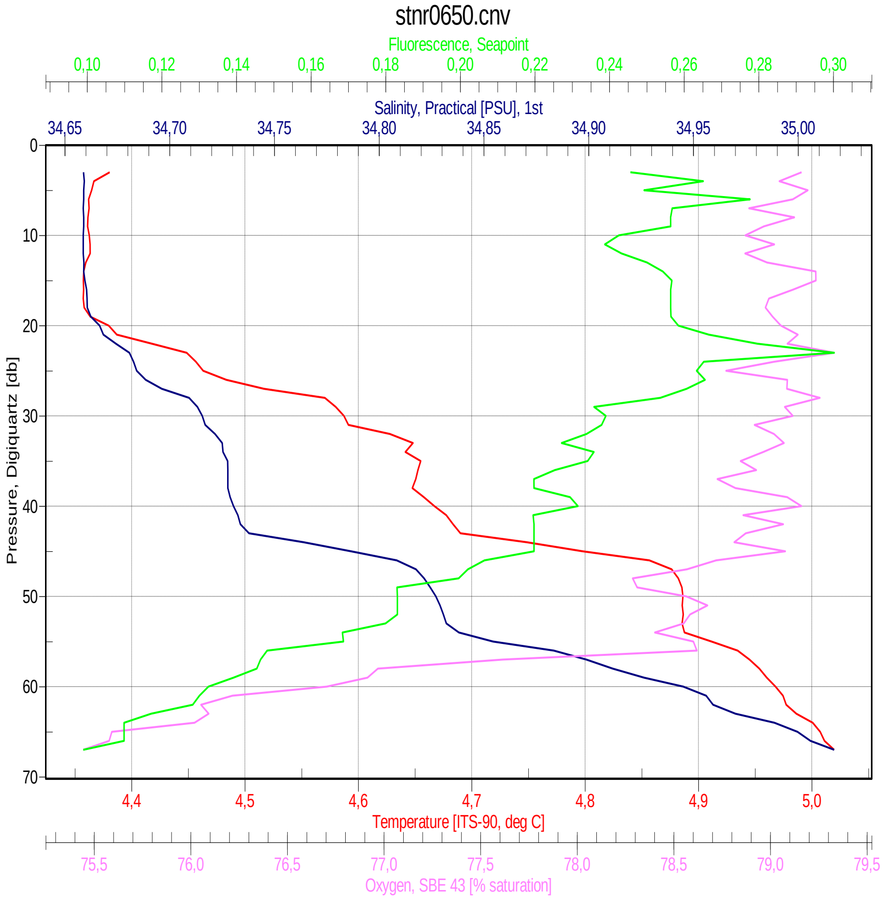
Major lithology: this core contains homogeneous dark gray clay.
The clay is thinly laminated containing thin (<0.3 cm thick) horizontal laminae.
These sediments represent background hemipelagic depositions. H2S smell during the recovery

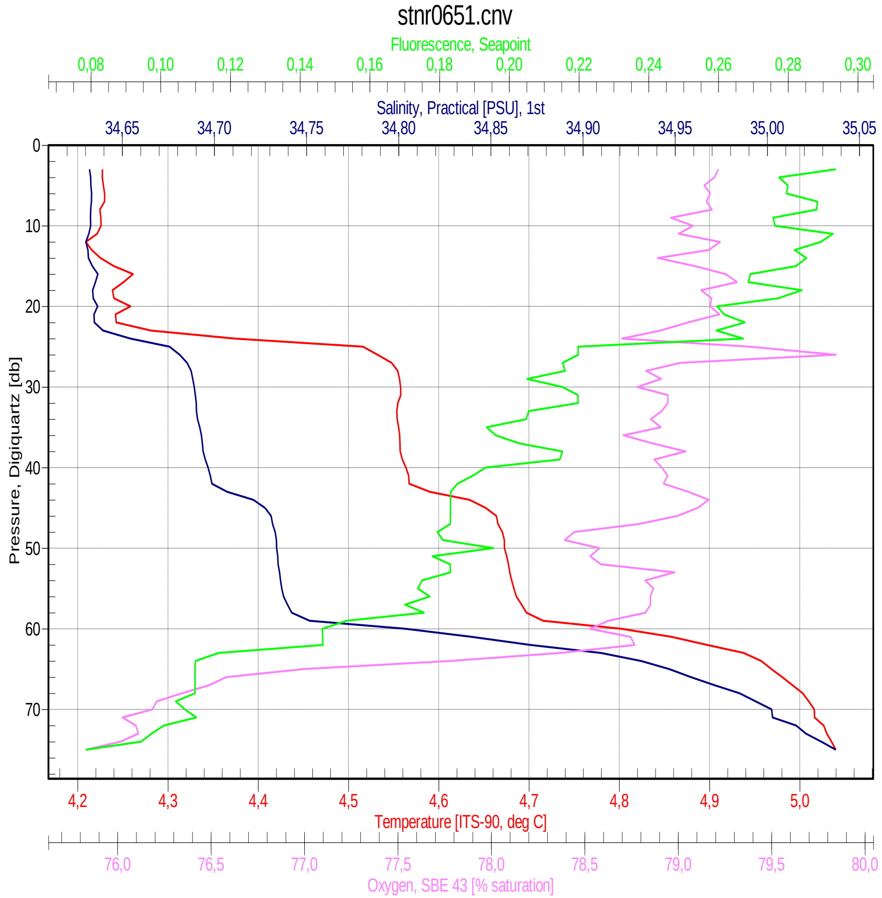


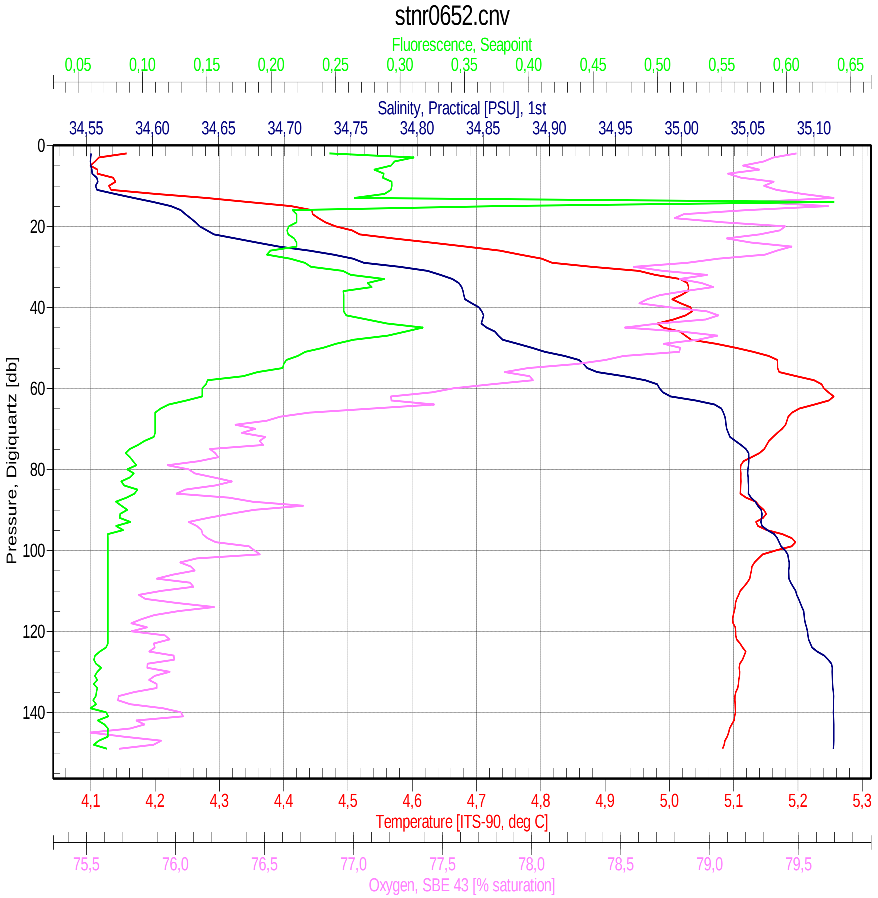

R/V Helmer Hansses Cruise CAGE 14-5 core GC11 ship station 857
Location Prins Karl Forland
Latitude 7837.708728 N Longitude 00827.454478 E Water depth 870.08 m
cm (b.s.f.)
section
visual description
134 cm bsf
LITHOLOGIC DESCRIPTION
Major lithology: this core contains homogeneous dark gray clay.
The clay is thinly laminated containing thin (<0.3 cm thick) horizontal laminae.
These sediments represent background hemipelagic depositions. H2S smell during the recovery
Sample log:
Micropaleontology
Rose bengal Micropalentology
Nannofossils
Microbiology
Pore water & methane
TOC
LEGEND:
Clay
Sand
Silt
Patchy mud
Black patch
Organic matter
Stiff sediment
Soupy sediment
Vugs
Shell fragments
Isolated pebbles and cobbles (< 5 cm) (red if oxidized)
Foraminifera
Tubeworm
Bioturbation
5 cm

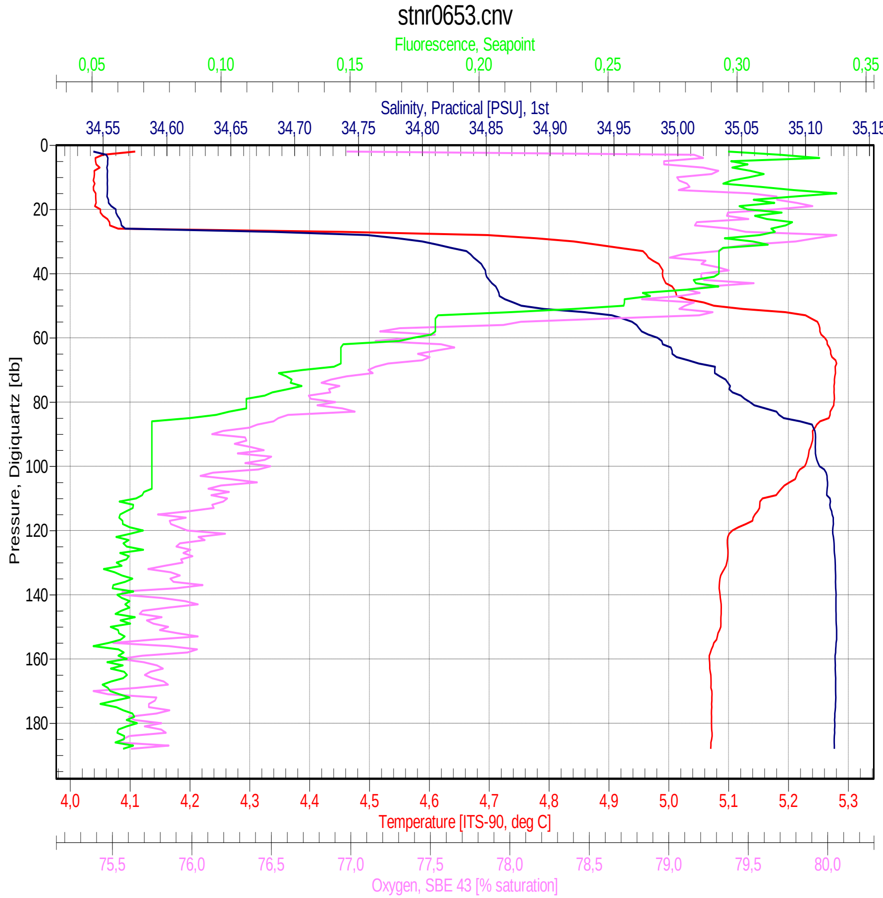


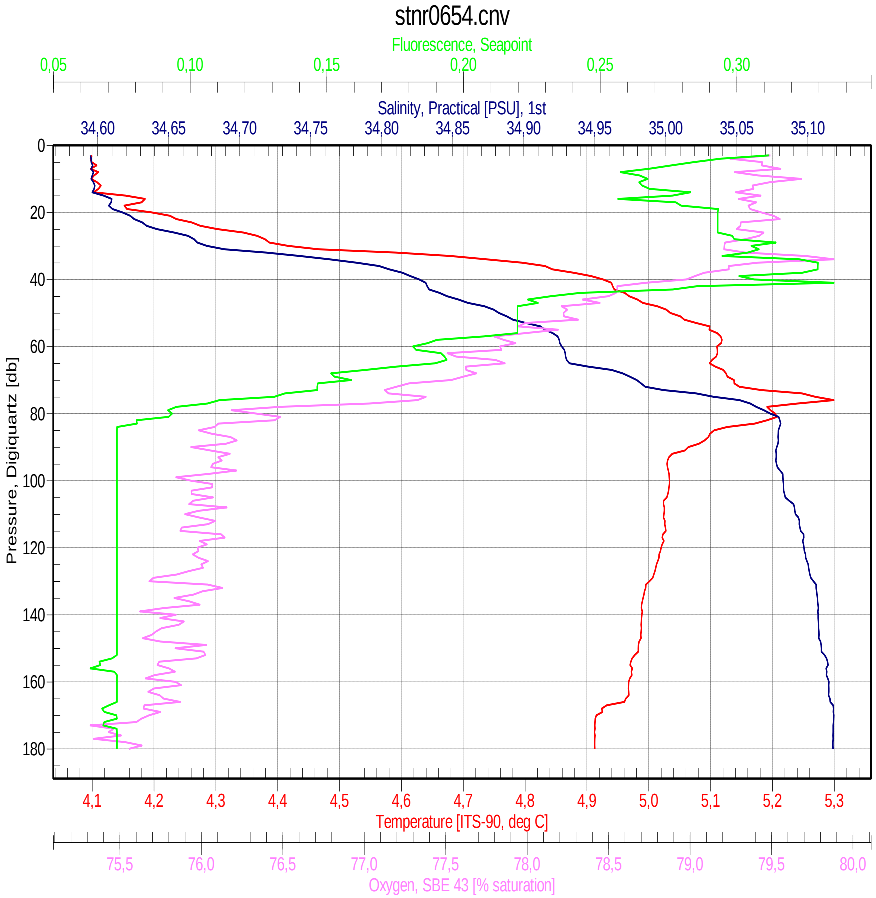
Appendix 3: Sediment core logs

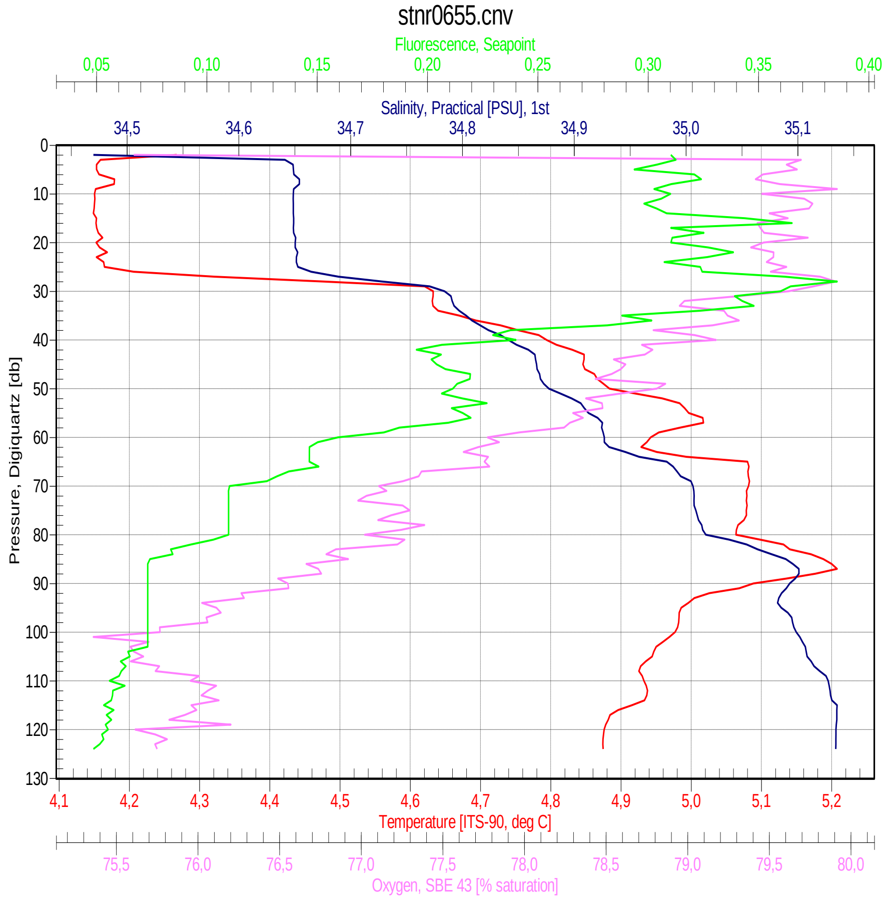

stnr0650.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]

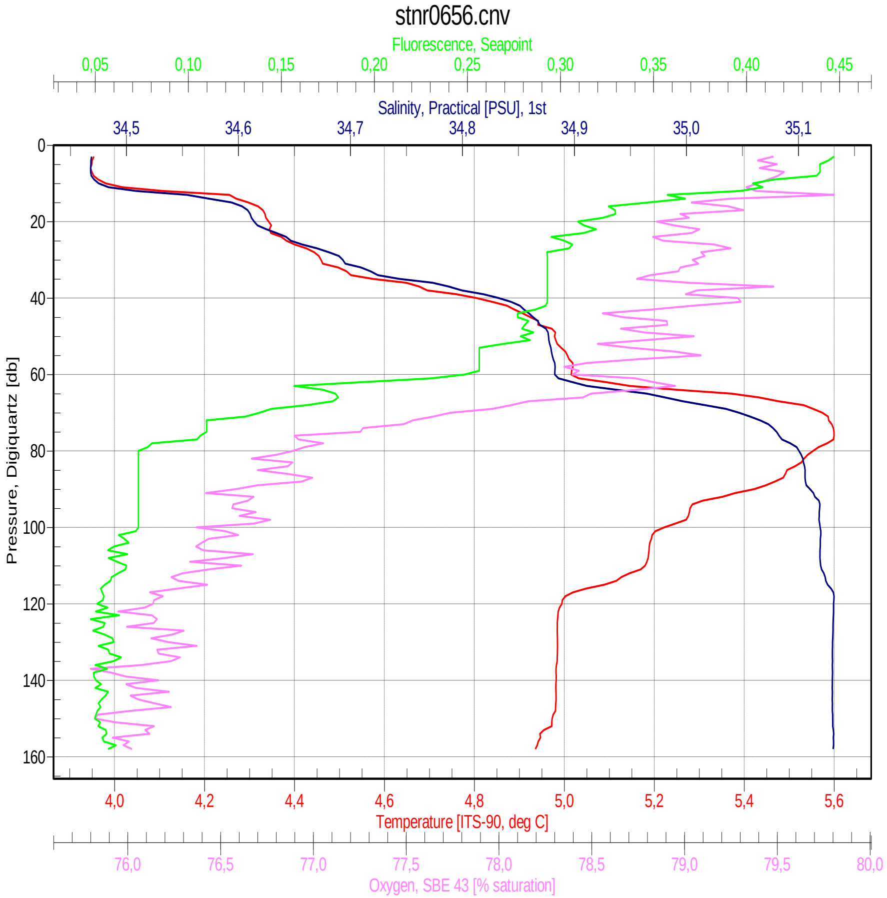

stnr0651.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]

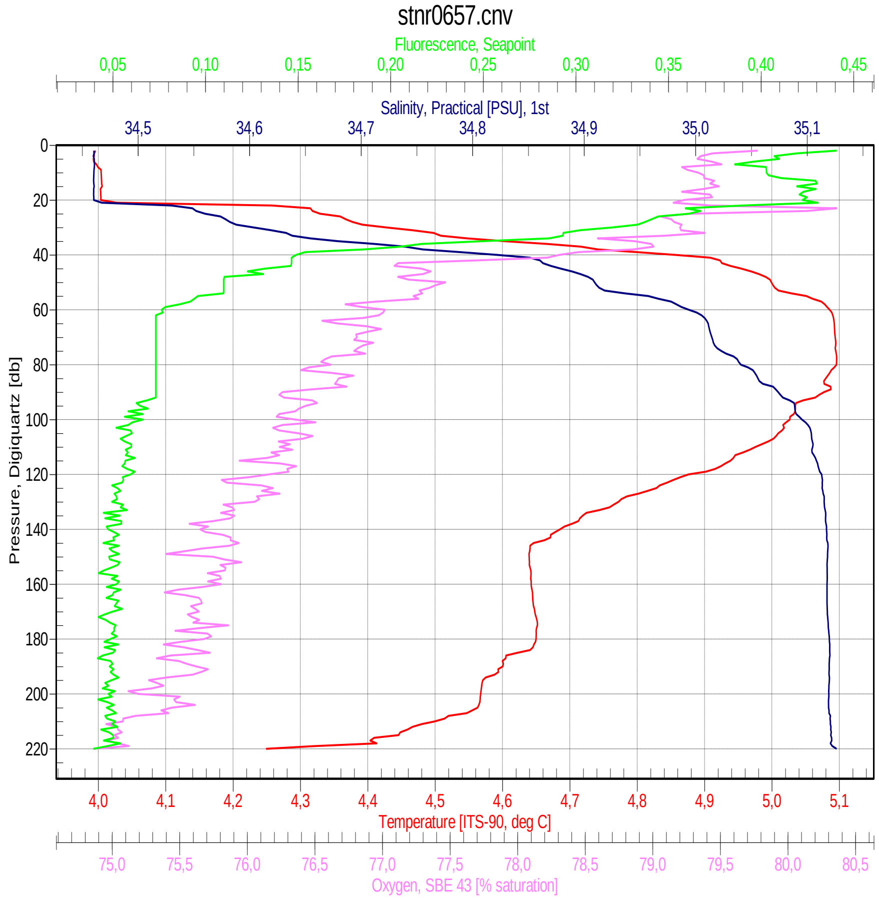

stnr0652.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]

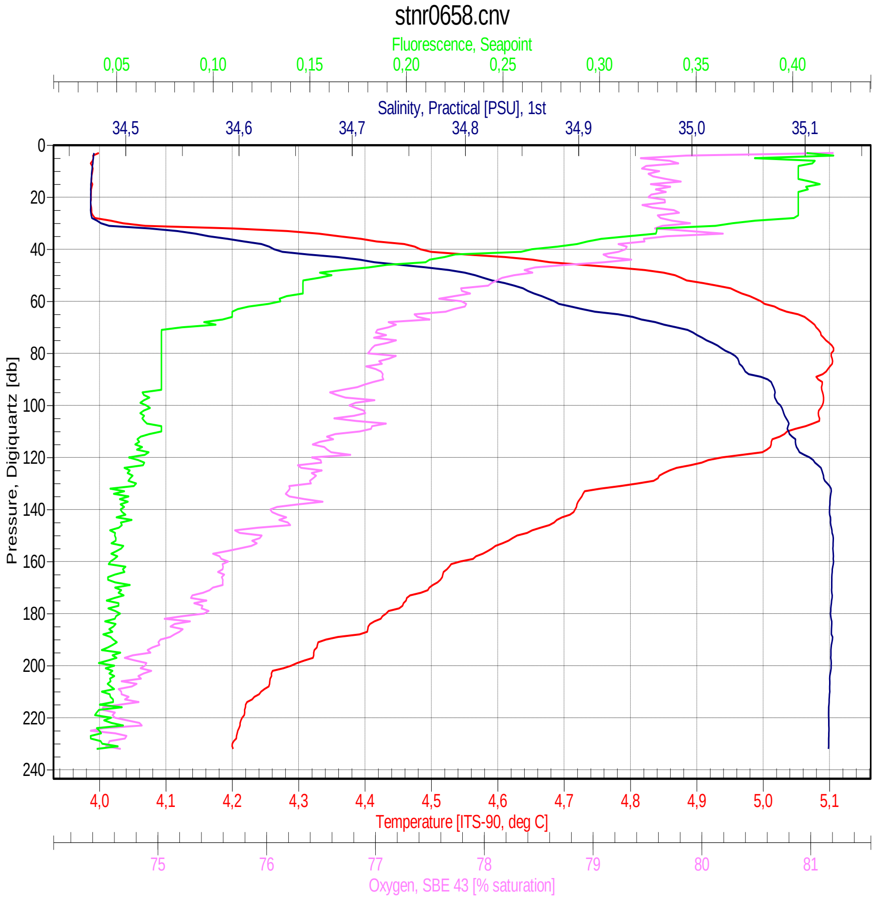

stnr0653.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]

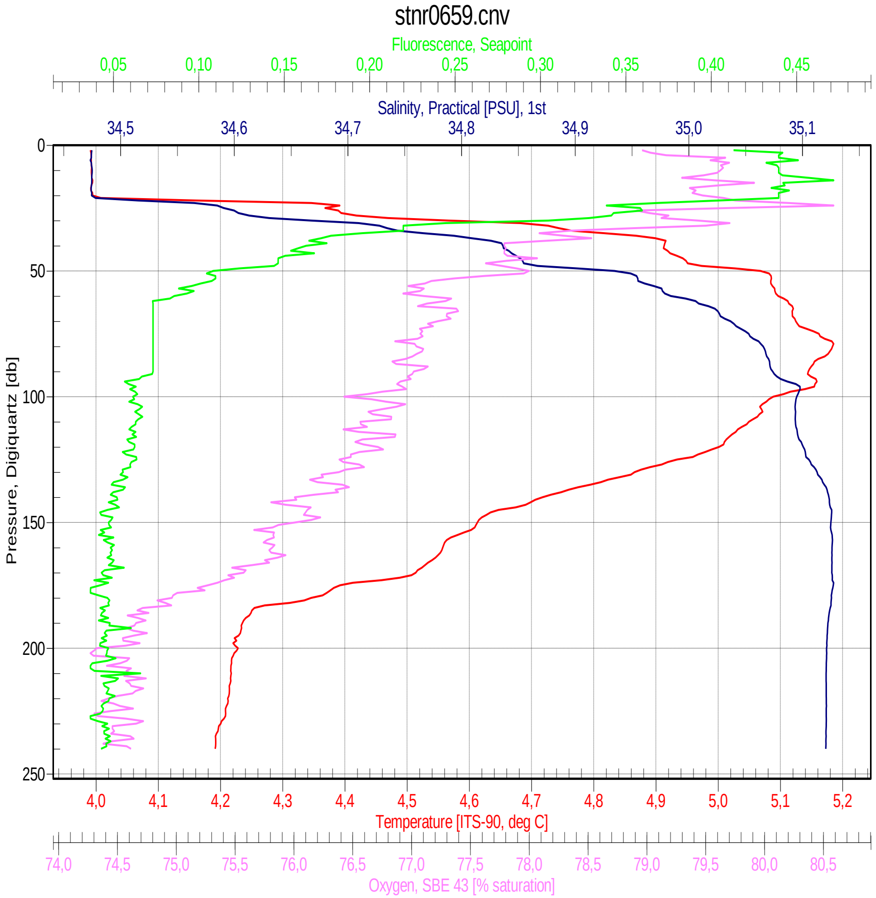

stnr0654.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]

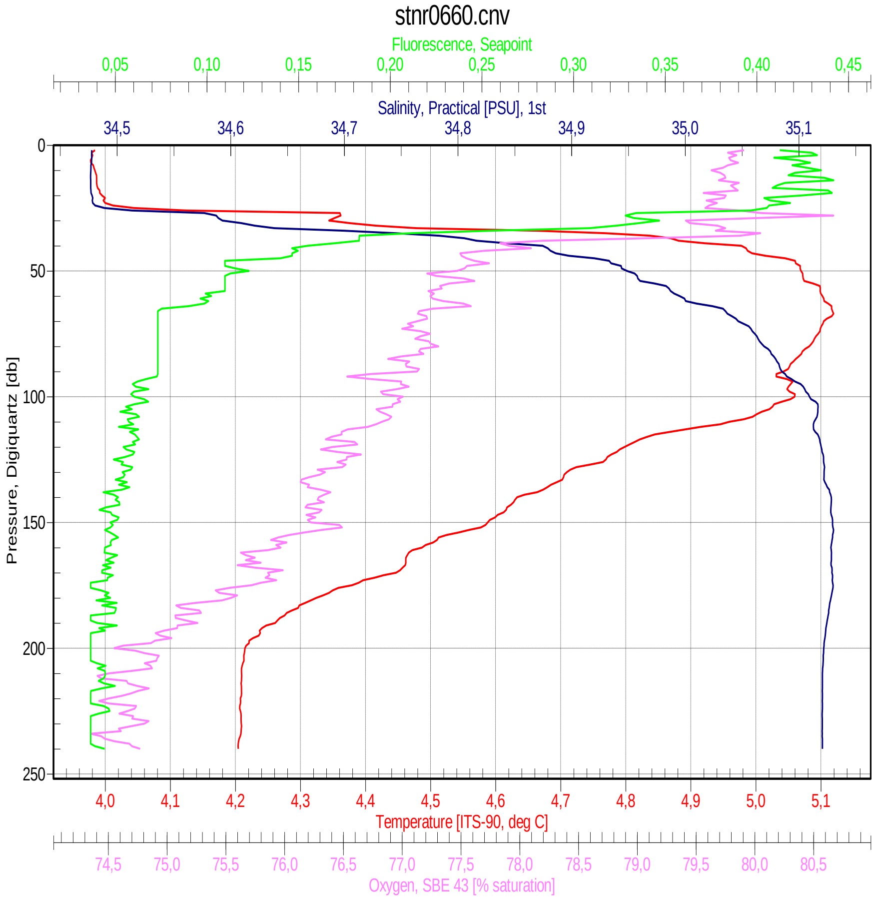

stnr0655.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]

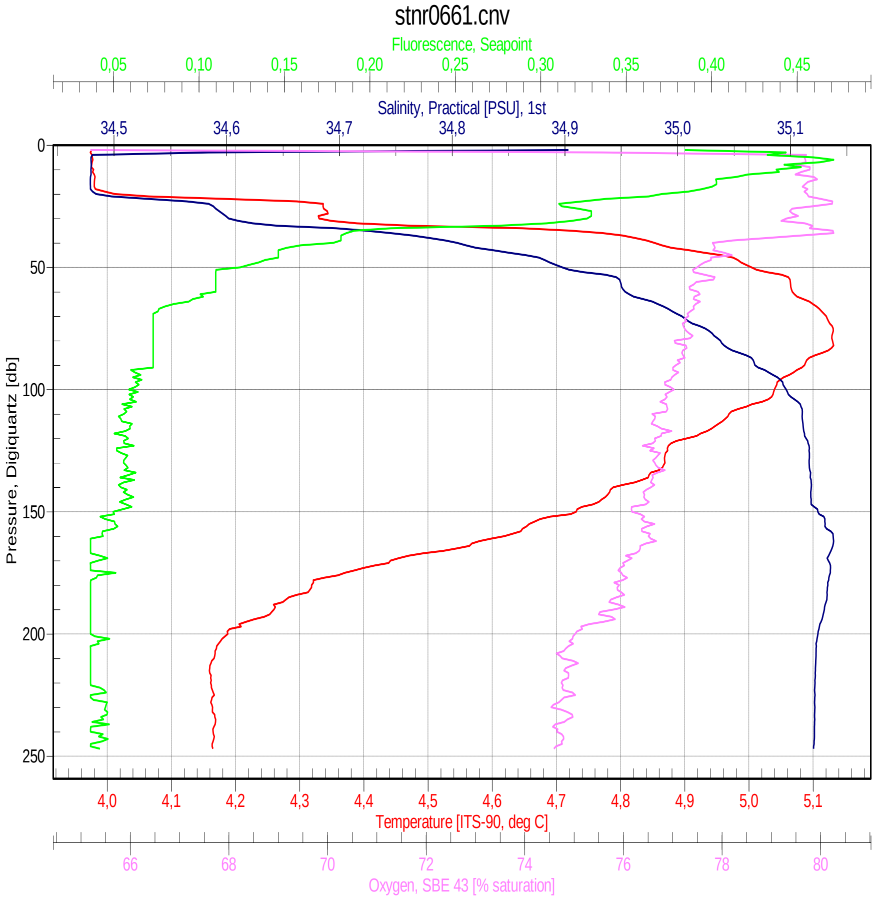

stnr0656.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30 0,35 0,40 0,45
Salinity, Practical [PSU], 1st
34,5 34,6 34,7 34,8 34,9 35,0 35,1
Pressure, Digiquartz [db]
0 20 40 60 80 100 120 140 160
4,0 4,2 4,4 4,6 4,8 5,0 5,2 5,4 5,6
Temperature [ITS-90, deg C]
76,0 76,5 77,0 77,5 78,0 78,5 79,0 79,5 80,0
Oxygen, SBE 43 [% saturation]

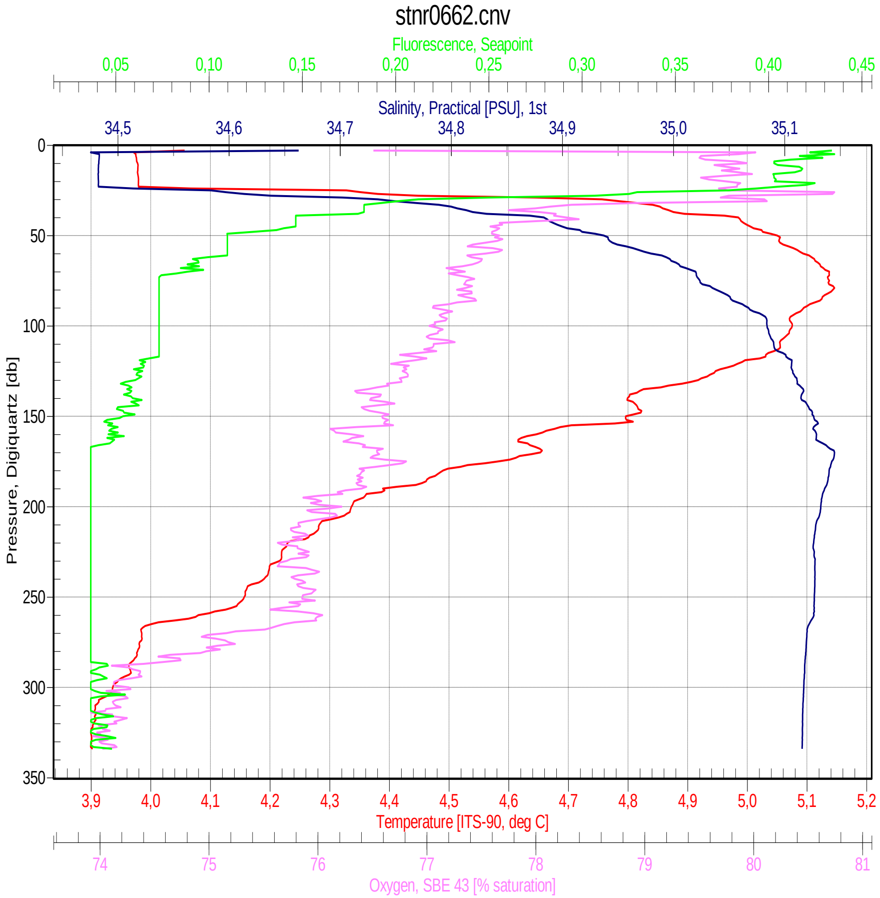

stnr0657.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30 0,35 0,40 0,45
Salinity, Practical [PSU], 1st
34,5 34,6 34,7 34,8 34,9 35,0 35,1
Pressure, Digiquartz [db]
0 20 40 60 80 100 120 140 160 180 200 220
4,0 4,1 4,2 4,3 4,4 4,5 4,6 4,7 4,8 4,9 5,0 5,1
Temperature [ITS-90, deg C]
75,0 75,5 76,0 76,5 77,0 77,5 78,0 78,5 79,0 79,5 80,0 80,5
Oxygen, SBE 43 [% saturation]

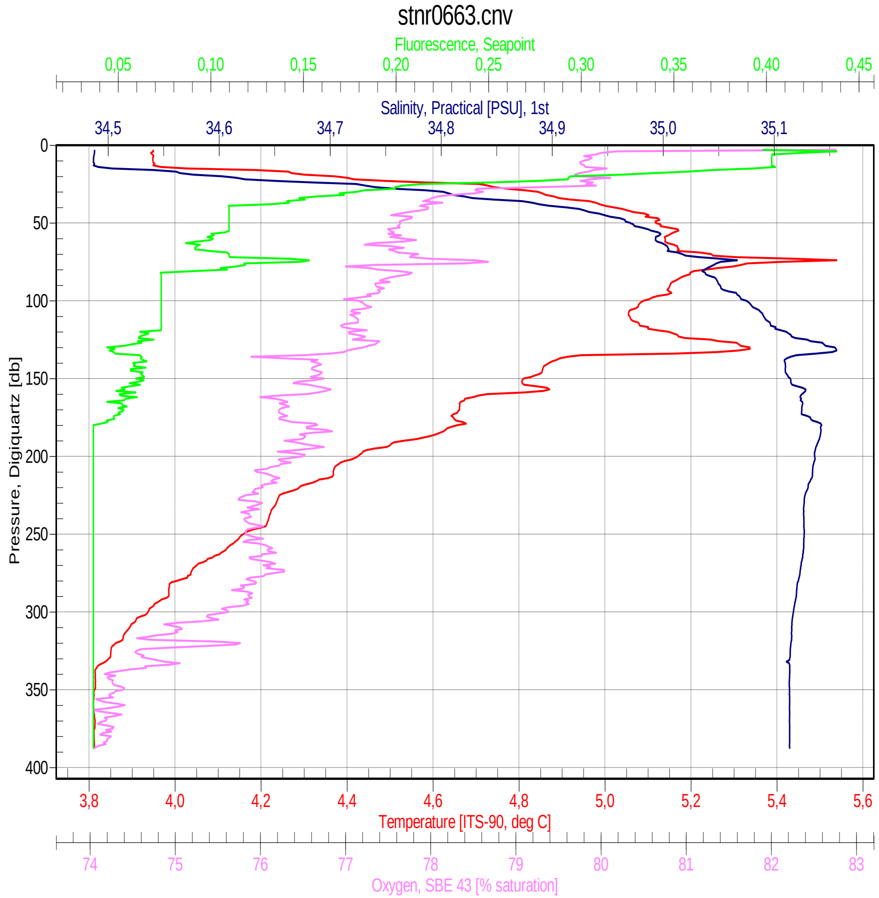

stnr0658.cnv
Fluorescence, Seapoint
0,05
0,10
0,15
0,20
0,25
0,30
0,35
0,40
Salinity, Practical [PSU], 1st
34,5
34,6
34,7
34,8
34,9
35,0
35,1
Pressure, Digiquartz [db]
0
20
40
60
80
100
120
140
160
180
200
220
240
4,0
4,1
4,2
4,3
4,4
4,5
4,6
4,7
4,8
4,9
5,0
5,1
Temperature [ITS-90, deg C]
75
76
77
78
79
80
81
Oxygen, SBE 43 [% saturation]

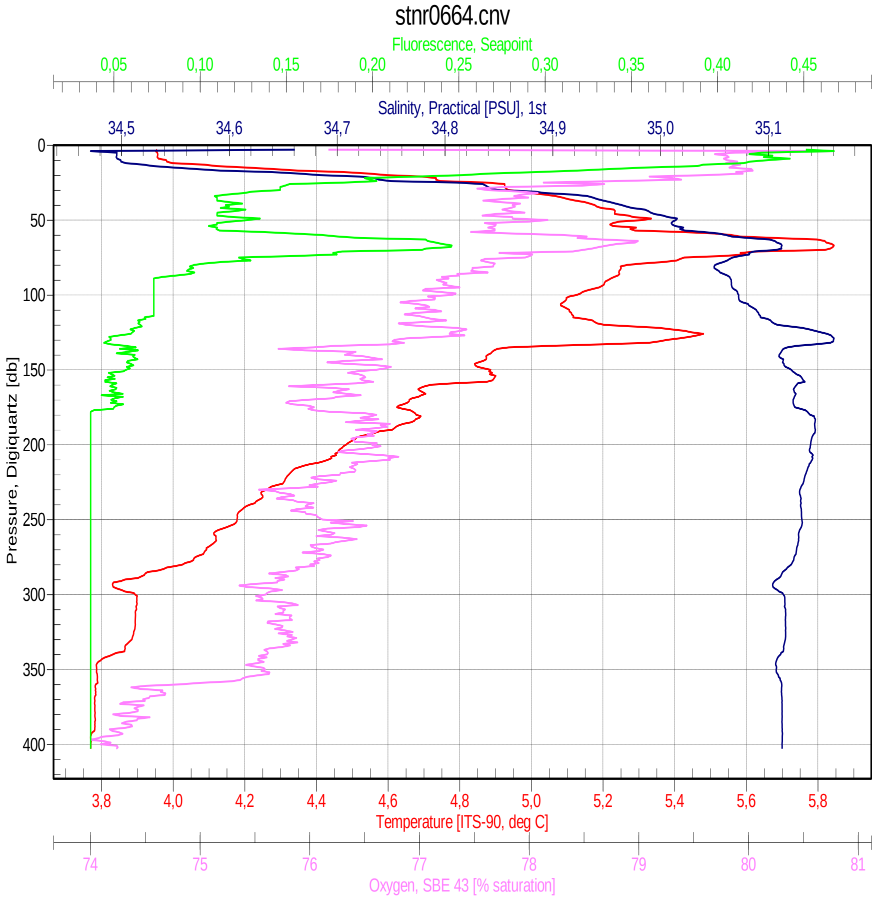

stnr0659.cnv
Fluorescence, Seapoint
0,05
0,10
0,15
0,20
0,25
0,30
0,35
0,40
0,45
Salinity, Practical [PSU], 1st
34,5
34,6
34,7
34,8
34,9
35,0
35,1
Pressure, Digiquartz [db]
0
50
100
150
200
250
4,0
4,1
4,2
4,3
4,4
4,5
4,6
4,7
4,8
4,9
5,0
5,1
5,2
Temperature [ITS-90, deg C]
74,0
74,5
75,0
75,5
76,0
76,5
77,0
77,5
78,0
78,5
79,0
79,5
80,0
80,5
Oxygen, SBE 43 [% saturation]

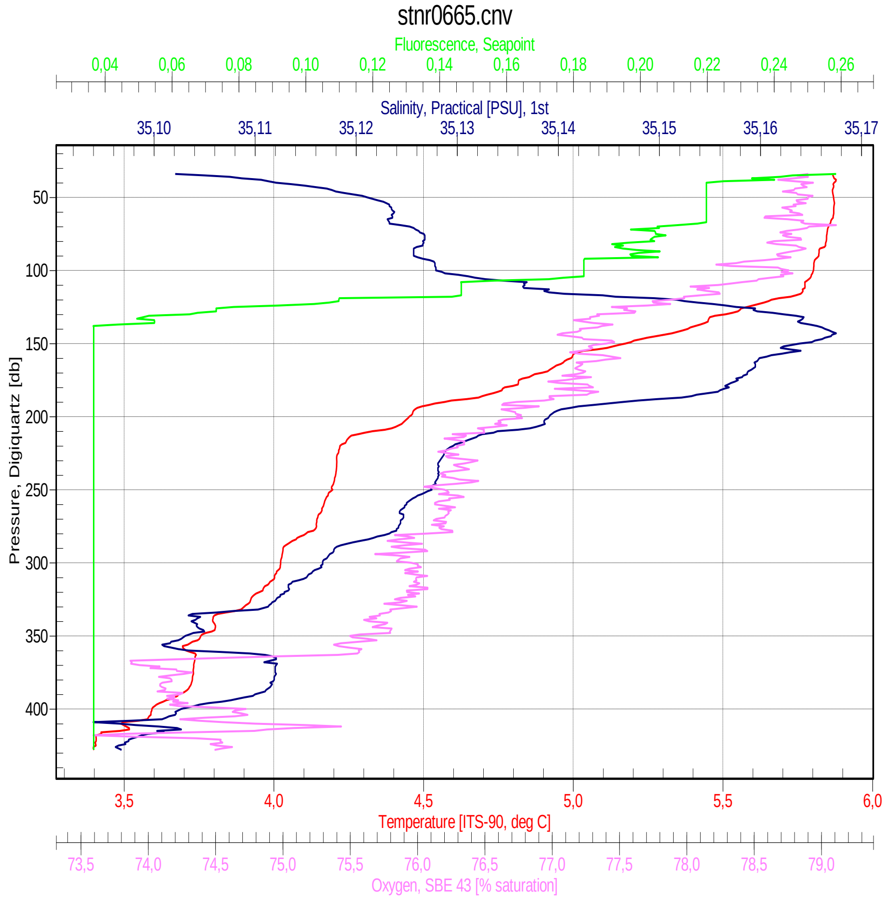

stnr0660.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30 0,35 0,40 0,45
Salinity, Practical [PSU], 1st
34,5 34,6 34,7 34,8 34,9 35,0 35,1
Pressure, Digiquartz [db]
0 50 100 150 200 250
4,0 4,1 4,2 4,3 4,4 4,5 4,6 4,7 4,8 4,9 5,0 5,1
Temperature [ITS-90, deg C]
74,5 75,0 75,5 76,0 76,5 77,0 77,5 78,0 78,5 79,0 79,5 80,0 80,5
Oxygen, SBE 43 [% saturation]

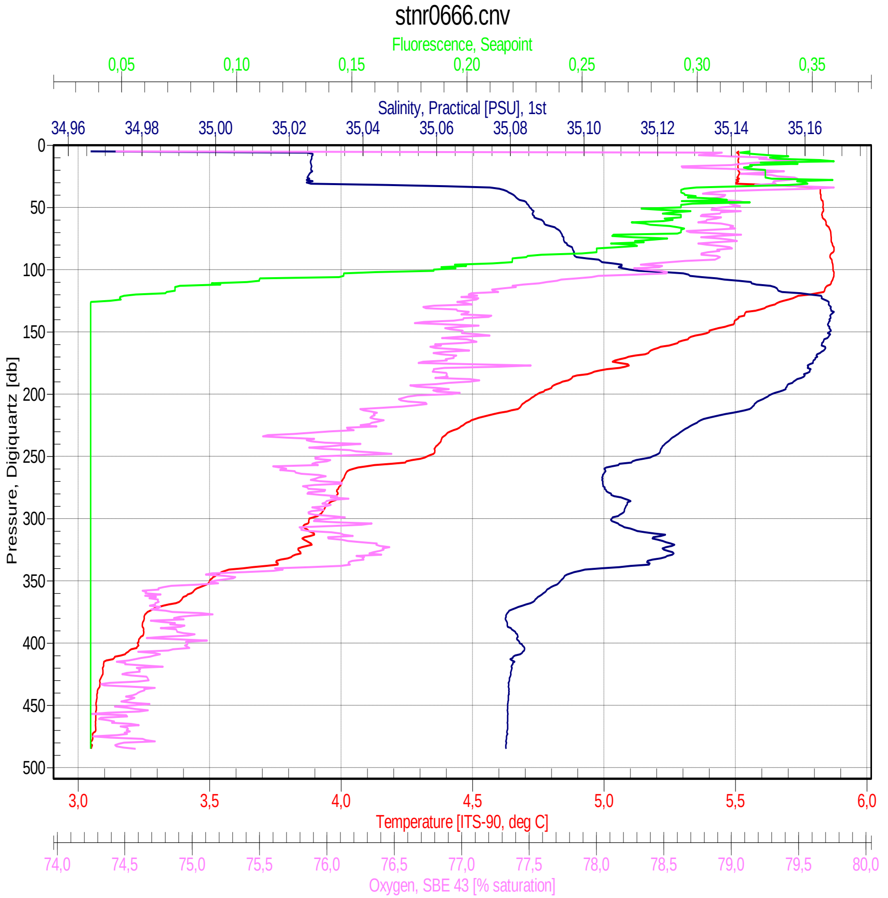

stnr0661.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30 0,35 0,40 0,45
Salinity, Practical [PSU], 1st
34,5 34,6 34,7 34,8 34,9 35,0 35,1
Pressure, Digiquartz [db]
0 50 100 150 200 250
4,0 4,1 4,2 4,3 4,4 4,5 4,6 4,7 4,8 4,9 5,0 5,1
Temperature [ITS-90, deg C]
66 68 70 72 74 76 78 80
Oxygen, SBE 43 [% saturation]

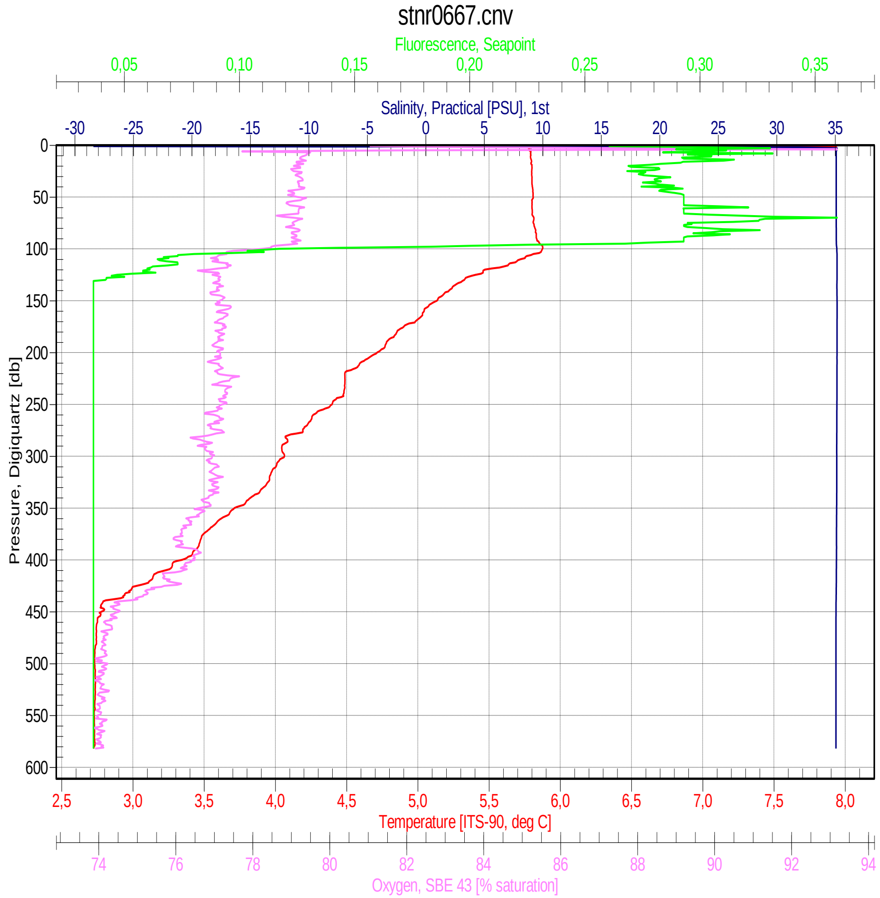

stnr0662.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30 0,35 0,40 0,45
Salinity, Practical [PSU], 1st
34,5 34,6 34,7 34,8 34,9 35,0 35,1
Pressure, Digiquartz [db]
0 50 100 150 200 250 300 350
3,9 4,0 4,1 4,2 4,3 4,4 4,5 4,6 4,7 4,8 4,9 5,0 5,1 5,2
Temperature [ITS-90, deg C]
74 75 76 77 78 79 80 81
Oxygen, SBE 43 [% saturation]

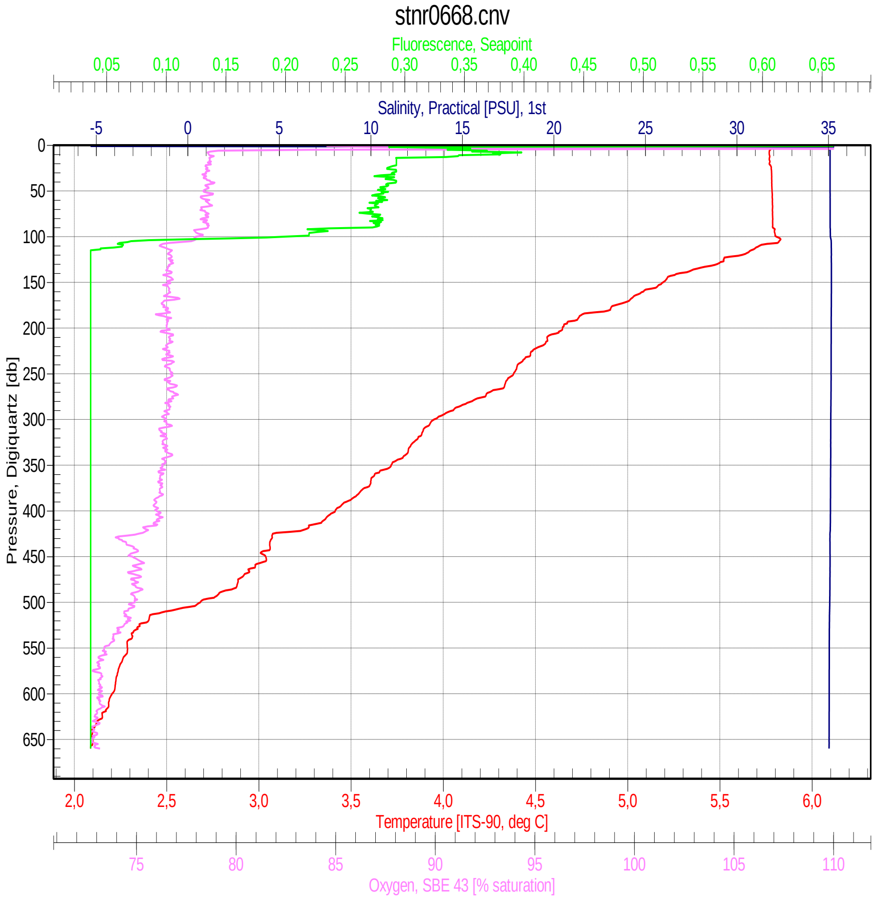

stnr0663.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30 0,35 0,40 0,45
Salinity, Practical [PSU], 1st
34,5 34,6 34,7 34,8 34,9 35,0 35,1
Pressure, Digiquartz [db]
0 50 100 150 200 250 300 350 400
3,8 4,0 4,2 4,4 4,6 4,8 5,0 5,2 5,4 5,6
Temperature [ITS-90, deg C]
74 75 76 77 78 79 80 81 82 83
Oxygen, SBE 43 [% saturation]

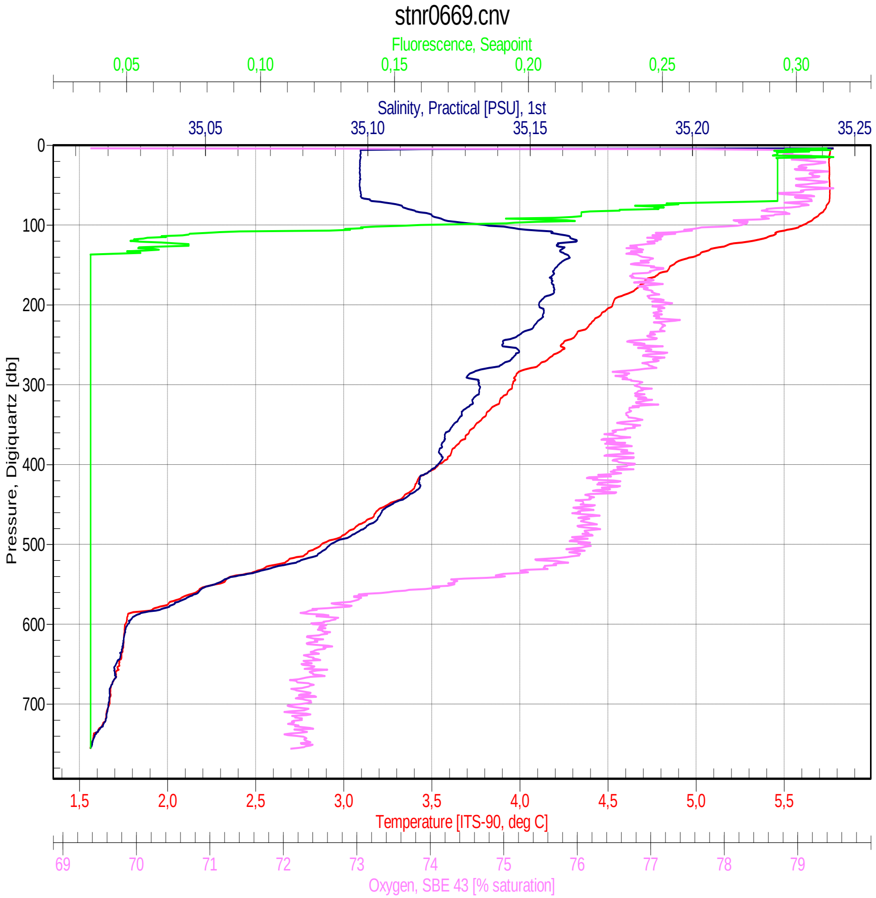

stnr0664.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30 0,35 0,40 0,45
Salinity, Practical [PSU], 1st
34,5 34,6 34,7 34,8 34,9 35,0 35,1
Pressure, Digiquartz [db]
0 50 100 150 200 250 300 350 400
3,8 4,0 4,2 4,4 4,6 4,8 5,0 5,2 5,4 5,6 5,8
Temperature [ITS-90, deg C]
74 75 76 77 78 79 80 81
Oxygen, SBE 43 [% saturation]

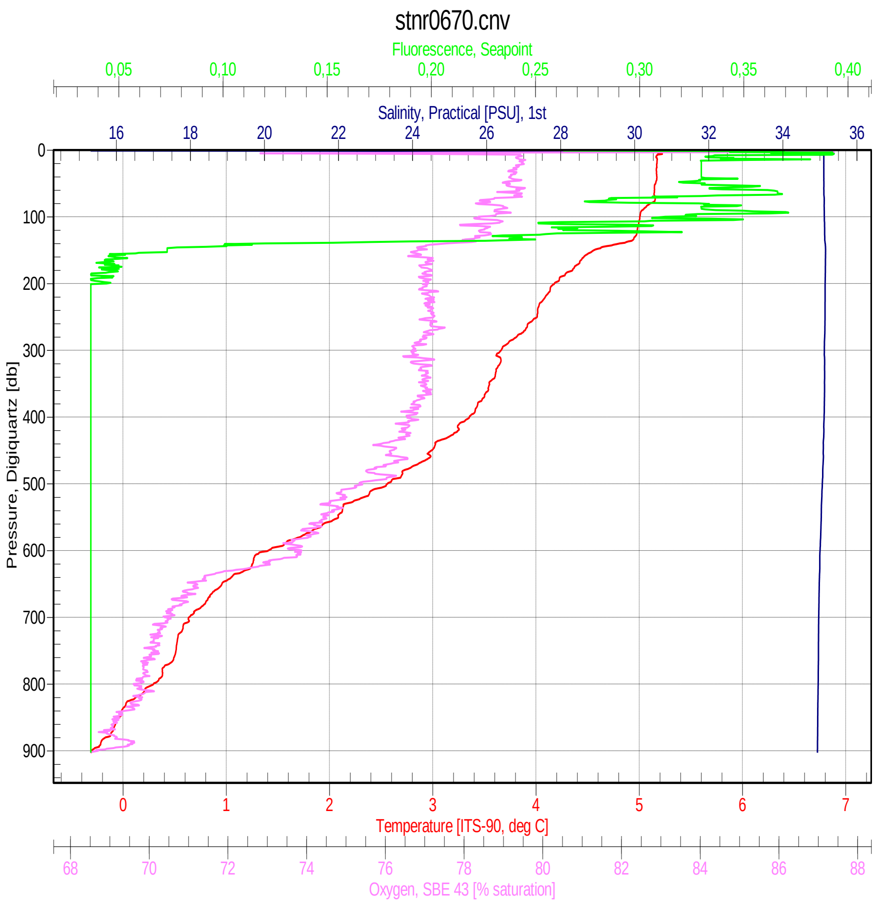

stnr0665.cnv
Fluorescence, Seapoint
0,04 0,06 0,08 0,10 0,12 0,14 0,16 0,18 0,20 0,22 0,24 0,26
Salinity, Practical [PSU], 1st
35,10 35,11 35,12 35,13 35,14 35,15 35,16 35,17
Pressure, Digiquartz [db]
50 100 150 200 250 300 350 400
3,5 4,0 4,5 5,0 5,5 6,0
Temperature [ITS-90, deg C]
73,5 74,0 74,5 75,0 75,5 76,0 76,5 77,0 77,5 78,0 78,5 79,0
Oxygen, SBE 43 [% saturation]

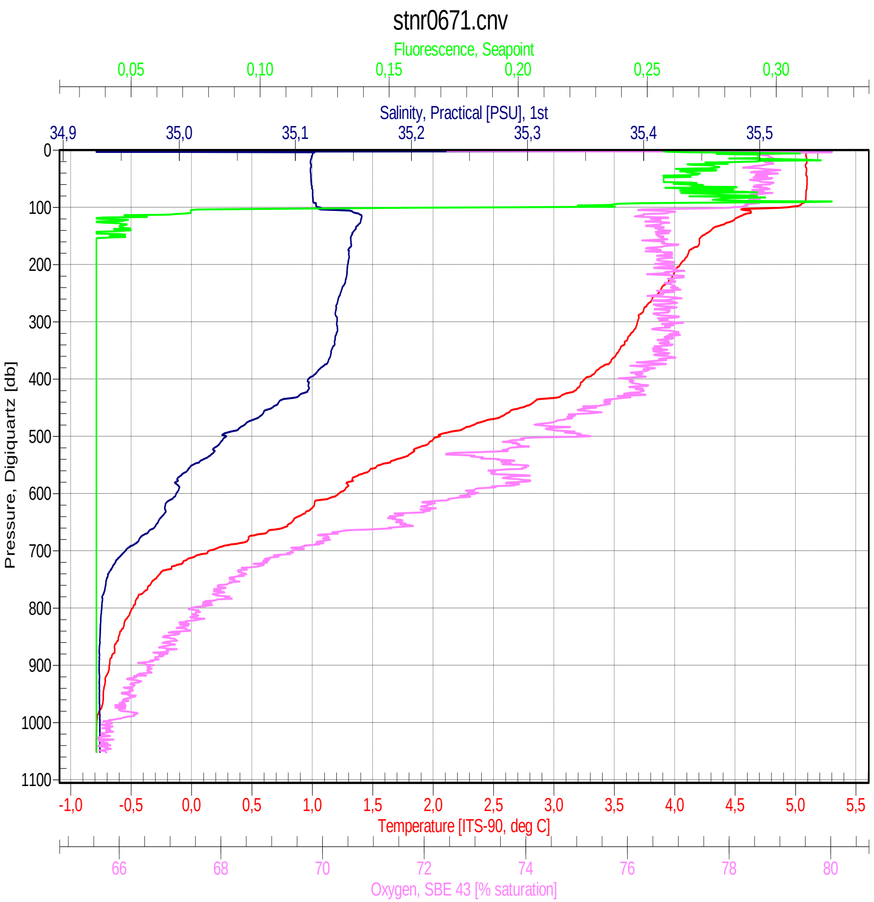

stnr0666.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]

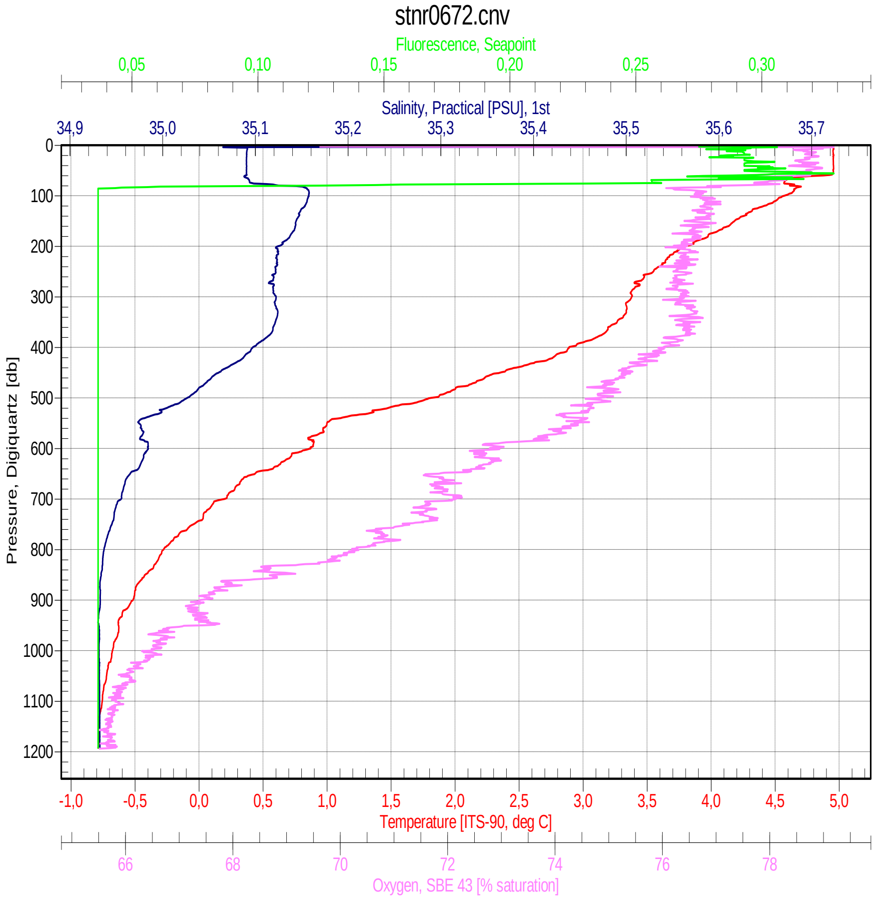

stnr0667.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]

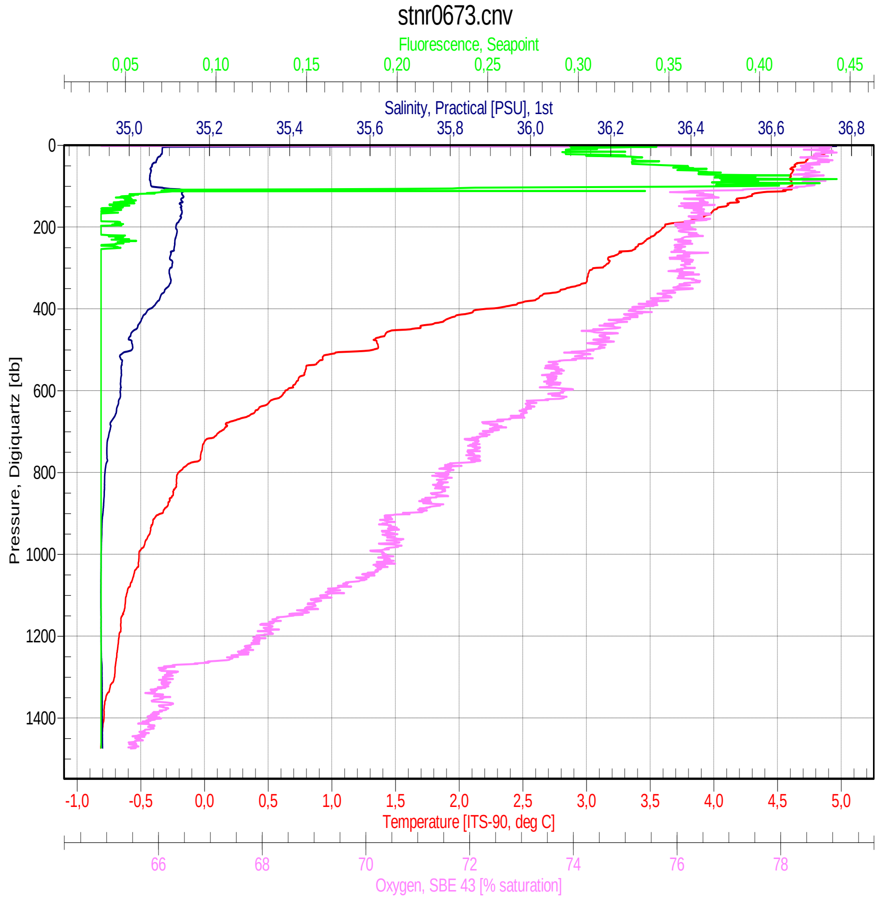

stnr0668.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30 0,35 0,40 0,45 0,50 0,55 0,60 0,65
Salinity, Practical [PSU], 1st
-5 0 5 10 15 20 25 30 35
Pressure, Digiquartz [db]
0 50 100 150 200 250 300 350 400 450 500 550 600 650
2,0 2,5 3,0 3,5 4,0 4,5 5,0 5,5 6,0
Temperature [ITS-90, deg C]
75 80 85 90 95 100 105 110
Oxygen, SBE 43 [% saturation]

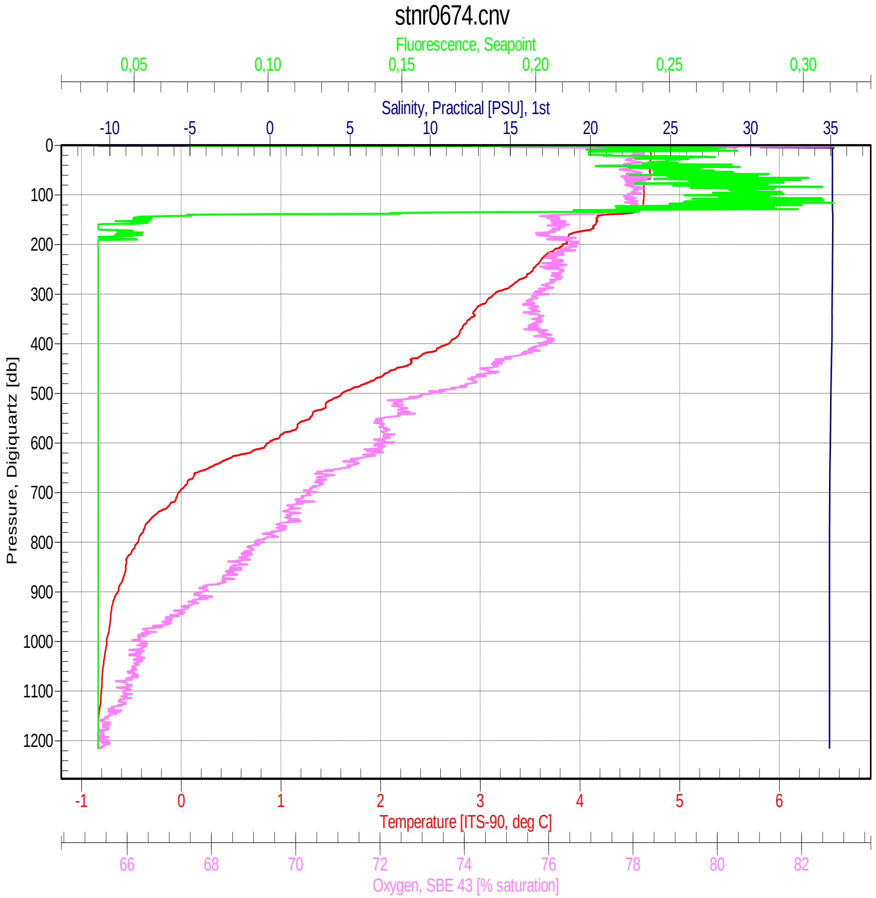

stnr0669.cnv
Fluorescence, Seapoint
0,05 0,10 0,15 0,20 0,25 0,30
Salinity, Practical [PSU], 1st
35,05 35,10 35,15 35,20 35,25
Pressure, Digiquartz [db]
0 100 200 300 400 500 600 700
1,5 2,0 2,5 3,0 3,5 4,0 4,5 5,0 5,5
Temperature [ITS-90, deg C]
69 70 71 72 73 74 75 76 77 78 79
Oxygen, SBE 43 [% saturation]

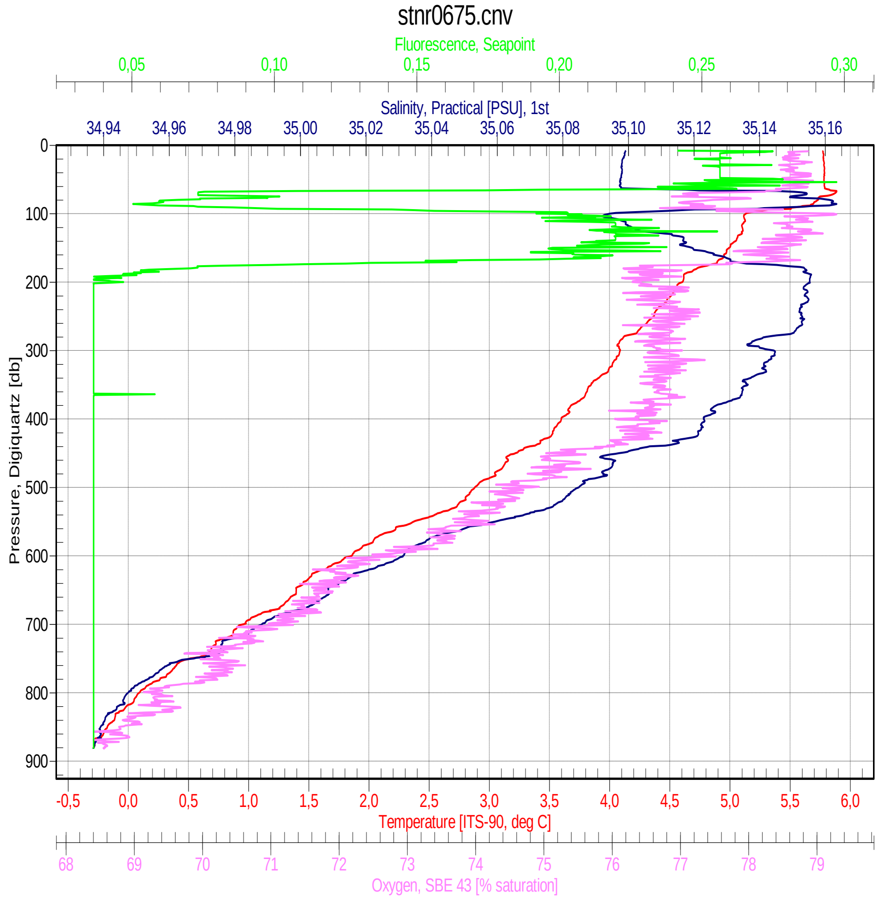

stnr0670.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]


stnr0671.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]


stnr0672.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]


stnr0673.cnv
Fluorescence, Seapoint
Salinity, Practical [PSU], 1st
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Oxygen, SBE 43 [% saturation]





Appendix 4: CTD station measurements

Micropaleontology (Giuliana, Katia)

Scientific objectives:

Tracking paleo-methane emissions
Establish the frequency of methane emissions
Establish whether there is a the link between climate warming and methane emissions.
Correlate methane emission events trough the study of cores from different areas affected by methane.
Local vs regional events.

Micropaleotology
Most of the sediment cores collected during the cruise offshore Prins Karl Foreland and Vestnesa Ridge have been sampled for micropaleontology (foraminifera and nannofossils; see Table of sampling in this report). The coring offshore Prins Karl Forland was done along a transect from the shelf crossing the 240m seep site down to 900m water depth that clearly indicate methane being released at the 240m shelf edge and between 350m and 400m water depth as indicated by preliminary analyses done during the CAGE14-1 cruise and repeated transect during CAGE 14-5 cruise. The coring in Vestnesa Ridge was done in a pockmark that has been considered active since flares and gas hydrate at 1.50 m b.s.f has been sampled in previous cruises and during CAGE 14-1 cruise. The main goal of this cruise is to collect cores from different areas (affected by methane) to correlate the methane emission events.

Further analyses of the samples will be dedicated to the investigation of the foraminiferal and nannofossils content. It has been suggested that the primary shell of benthic foraminifera and the secondary carbonate authigenic precipitation on their shell can be used as a proxy of methane seepages in the marine environment. Negative carbon-isotopic compositions of foraminifera tests have been reported from methane seep environments, and it has been suggested that some of these species record distinct 13C-depletions inherited from methane (Sen Gupta and Aharon, 1994; Sen Gupta et al., 1997; Hill et al., 2004; Martin et al., 2007; Panieri et al., 2009, 2012, 2014a, b). With the purpose to better understand the processes that produce these negative values that are partially unknown and trace past methane emissions in the investigated areas benthic foraminifera will be identified, counted and selected for geochemical measurements. For some of the cores, the samples taken every cm from 0 to 5 of sediment have been preserved in Rose Bengal staining method to identify the living benthic foraminifera.

The nannofossils content will be investigated with the main goal to reconstruct paleoenvironmental condition during the last deglaciation. In addition, the samples collected from the first 11 cm of all cores from different bathymetry setting will provide the community at the time of sampling.

Core number	StNr	Latitude	Longitude	Depth	Recovery (cm)	Preliminary observations
GC01	847	7839.252518 N	00934.191713 E	202.9	41	
GC02	848	7839.544467 N	00933.308653 E	223.66	14(core catcher)	
GC03	849	7839.220567 N	00929.111584 E	235.93	64	
GC04	850	7839.387721 N	00925.952282 E	246.1	34	
GC05	851	7839.324226 N	00925.991531 E	244.35		
GC06	852	7839.335856 N	00925.996991 E	245.49	0	
GC07	853	7839.330437 N	00926.015575 E	245.79	77	
GC08	854	7839.279150 N	00925.937467 E	245.12	28.5	
GC09	855	7838.020455 N	00843.294787 E	716.37	184	
GC10	856	7837.712663 N	00827.356397 E	869.61	84	
GC11	857	7837.708728 N	00827.454478 E	870.08	134	H2S smell
GC12	858	7837.422418 N	00742.387984 E	1185.99	260	H2S smell
GC13	859	7948.550732	00449.194117	1809.65	59	

		N	E			
GC14	860	7947.576162 N	00446.686197 E	2040.34	156	
GC15	861	7946.947481 N	00447.349899 E	2203.08	194	
GC16	862	7945.094796 N	00422.026709 E	2613.87	212	
GC17	863	7944.106663 N	00432.826481 E	2709.16	248	
GC18	864	7936.875830 N	00443.213176 E	2916.4	238	
GC19	865	7933.924484 N	00455.304687 E	2848.33	272	
GC20	866	7934.714154 N	00458.224067 E	2850.49	276	
GC21	867	7913.440809 N	00433.195537 E	1650.49	73	
GC22	868	7912.869442 N	00430.997697 E	1611.13	core catcher	
GC23	869	7912.211850 N	00433.286131 E	1554.21	268	
GC24	870	7907.661678 N	00534.972149 E	1308.09	270	
GC25	871	7900.115171 N	00656.013477 E	1208.8	260	
GC26	872	7841.561633 N	00815.720010 E	888.28	241	
GC27	873	7841.375787 N	00816.617727 E	881.45	215	
GC28	874	7841.562138 N	00836.987408 E	727.37	198	

Spitsbergen Fault Zone Slide Complex (Giacomo Osti)

In the study area of the Spitsbergen Fault Zone Slide Complex 8 cores (see table below) have been acquired. Two of them were located at the very distal part of the lobe on the southern slide. One was located at the distal part of the northern main slide (3000m). Five of them have been acquired from the shallowest part descending towards the deepest slope along the northern slide. This slide presents several mass movement events within the main slide scar. Two new 2D seismic lines have been acquired. One cuts diagonally the southern slide and show the along-slope section of the northernmost slide. The second shows the longitudinally section of the northern slide.
The main goal of the coring activity was to penetrate through the slide scar infilling and reach the slide reworked material to eventually date the slide events, and to have a sedimentological overview of the post slide event deposition in locations within the northernmost slide scar.
All the cores have been logged, split and described. They will be sampled for dating in Tromsø after running them through the X-ray scanner.

Core number	StNr	Latitude	Longitude	Depth	Recovery (cm)
GC13	859	7948.550732 N	00449.194117 E	1809,65	59
GC14	860	7947.576162 N	00446.686197 E	2040,34	156
GC15	861	7946.947481 N	00447.349899 E	2203,08	194
GC16	862	7945.094796 N	00422.026709 E	2613,87	212
GC17	863	7944.106663 N	00432.826481 E	2709,16	248
GC18	864	7936.875830 N	00443.213176 E	2916,4	238
GC19	865	7933.924484 N	00455.304687 E	2848,33	272
GC20	866	7934.714154 N	00458.224067 E	2850,49	276

Core locations and recovery of gravity cores from the Spitsbergen fault zone slide complex