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Geochemical observations on Hydrate Ridge, Cascadia Margin during R/V BROWN-ROPOS cruise, August 1998.

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1. INTRODUCTION

1.1 Science summary

The main objective of the benthic program within TECFLUX is to determine the effect of widespread hydrate formation in the Cascadia margin (Figure 1) on element mobilization, transport and release at the seafloor. In this margin, we have an opportunity to study locations where fluids and gases from hydrate decomposition are escaping from the accretionary prism as well as sites in which hydrates appear to be undergoing very little decomposition. During the 1998 field program we concentrated at the sites of active gas discharge.

Decomposition of the hydrates at sites of localized flow is probably driven by temperature fluctuations within the accretionary prism caused by upward advection of warm fluids (Westbrook et al., 1994). Geochemical consequences of hydrate destabilization and venting of fluids include: 1) a large release of methane; 2) a release of water enriched in ^{18}O; 3) a potential discharge of elements which are enriched in fluids found below the BSR; 4) the development of benthic biological communities; and 5) the precipitation of carbonate minerals.

The massive and rapid release of methane on the second accretionary ridge has been previously documented by mapping of a methane-rich plume in the water column (Suess et al., 1998). The only quantitative measurements of fluid expulsion and methane fluxes on the second accretionary ridge were those obtained by a submersible-deployed benthic barrel during Alvin dive 2283 (Linke et al., 1994).

1.2 Background information

1.2.1 Tectonic setting

The Juan de Fuca Plate is currently being subducted beneath the North American Plate along the Oregon-Washington continental margin (Riddihough, 1984; Duncan and Kulm, 1989). The incoming upper Miocene oceanic crust is covered by up to 3.5 km of turbidites and hemipelagic deposits. The lowermost portion of this sediment package is subducted beneath the continental slope, whereas the upper portion is accreted to the margin. Landward vergence prevails along the lower slope of Washington (Carson et al., 1974; Silver,

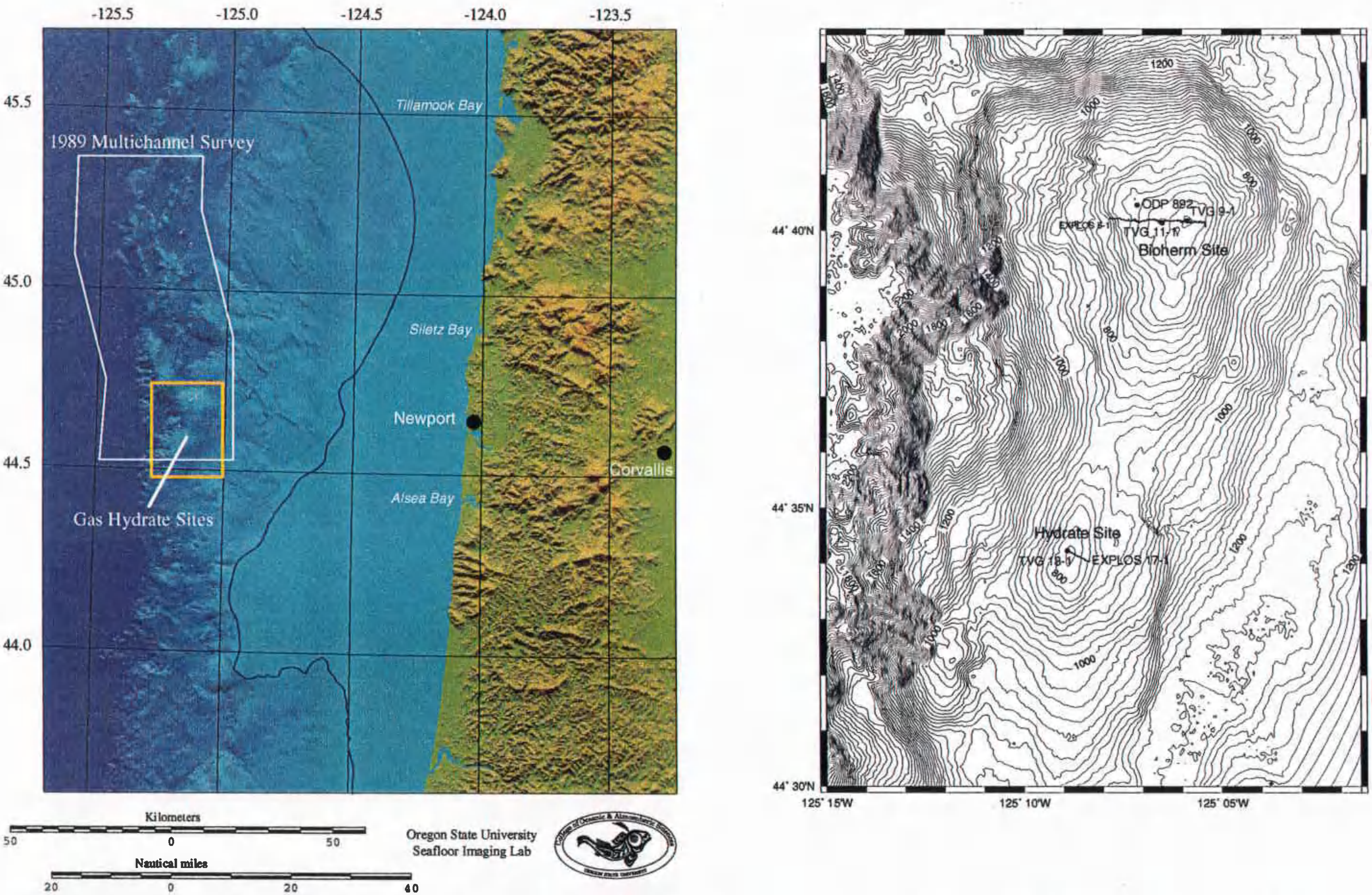


Figure 1. Bathymetric map (color panel) of the central Oregon coast and continental margin showing the location of the 1989 multichannel seismic site survey (McKay et al, 1992) and the general location of the gas hydrate study site of R/V SONNE Hydrotrace Expedition. Image produced by C. Goldfinger, COAS. Right-hand panel is a bathymetric map of the "second accretionary ridge" showing the location of the northern "bioherm" site, near ODP 892 and the SONNE sampling sites, and the southern "hydrate" site. Unpublished data presented by Suess et al, 1996.

1972), and northern Oregon (Kulm et al., 1973, Carson, 1977); seaward-vergence dominates central and southern Oregon (Kulm and Fowler, 1974, Seely et al., 1974). Multi-channel seismic (MCS) data collected across the central Oregon accretionary prism have been used to document how the structural style and stratigraphy of the prism control the pattern of fluid flow observed at the seafloor (Kulm et al., 1986). A complete analysis of the structure of the region based on a over 2000 km of MCS data collected in preparation for ocean drilling (Leg 146) has been presented by McKay et al. (1992). In an east-west transect along 44° 38.66' N fluid discharge has been documented by a series of *Alvin* dives associated with the frontal thrust and the backthrust, as well as along erosional exposures of sandy strata (Kulm et al., 1986; Moore et al., 1990; Orange and Breen, 1992). At 44° 40.45'N, venting of fluids was observed at a site where the backthrust intersects an erosional canyon on the second accretionary ridge in 675 m of water. These fluids were sampled in a time sequence using a benthic barrel deployed by *Alvin* over active discharge sites (Suess et al., 1998). The stations occupied for these experiments are located on the second accretionary ridge (675 m, Dive 2283), the deformation front (>2500 m, Dive 2285) and the seaward accretionary wedge (2046 m, Dive 1907). The results have shown that fluxes of methane from the Cascadia seeps can reach values as high as 2000 g m^2 y^{-1} (Carson et al., 1990; Linke et al., 1994). A fluid flow rate of 1765 ± 20 l m^{-2} y^{-1} was measured with a thermistor flow meter at site 2283 (Linke et al., 1994).

1.2.2 Drilling results

Deep sea drilling in this margin was conducted during ODP Leg 146 with the aim of further documenting the patterns of fluid flow and sediment deformation within the accretionary wedge (Westbrook et al., 1994). Active advection of fluids was documented by packet test results, as well as by geochemical and temperature anomalies. Thermogenic hydrocarbons detected at very shallow depths indicate migration of fluids from 1 to 4 km (Whiticar et al., 1995). Chemical analysis of interstitial water samples suggests a common deep source for the fluids recovered at drill sites off Vancouver and Oregon. This deep-seated fluid seems to be characterized by higher than seawater concentrations of Li, Si, Ca and Sr, a depletion of Cl relative to seawater, non-radiogenic strontium isotopes and depletion of d^{18}O (Kastner et al., 1995b; Kastner et al., 1998).

Recent advective flow at Site 892 is also documented by two *in situ* temperature measurements which lie 1.6 to 2.5 °C above the linear geothermal gradient of 51°C/km (Westbrook et al., 1994). Downhole logs and vertical seismic profiles (VSP) at Site 892 established that the BSR, commonly observed in sediments from many gas hydrate provinces, is caused by free gas below 71 mbsf. The presence of methane hydrates above this depth was inferred by methane and chlorinity measurements. No massive accumulations of gas hydrate were encountered at either site 889 or 892; rather, most of the hydrate appears to be disseminated within the pore space. Temperature measurements and dilution of pore waters from these sites suggest that less than 10-40% of the pore space is filled with hydrates. Solid gas hydrate recovered at site 892 between 2 and 19 mbsf, was not associated with the BSR. This near-surface deposit contains up to 10% H_2S (Kastner et al., 1995a, Whiticar et al., 1995).

1.2.3 Sonne Hydrotrace program (SO110)

An international team of researchers, sailing on the German research vessel RV SONNE, recently completed a series of field studies on the convergent continental margin off Oregon. The expedition, coordinated by scientists at GEOMAR (Research Center for Marine Geoscience at the University of Kiel, Germany), included the Canadian remotely operated unmanned submersible "ROPOS", and other TV-guided instruments and samplers deployed from the SONNE. During this cruise, nearly 50 kg of solid methane gas hydrates was recovered from the seafloor on the south section of the 'second accretionary ridge' at a water depth of 785 m (Station SO110/18, Figure 1). Video surveys of the area indicate that the seafloor there is paved by hydrates. The pavement is extensive (100's of m^2) and lined with bacterial mats. Communities of vent organisms and carbonate precipitates are absent. The trapped gas phase in the hydrate contained 93.7% methane, 5.1% carbon dioxide and 1.2% hydrogen sulfide. The carbon isotopic composition of the methane was -67.2 $^{o}/_{oo}$ and that of the carbon dioxide was -31.9 $^{o}/_{oo}$. The massive hydrate appears in layers up to 10 cm thick, with thin beds of hydrogen sulfide rich sediment and $CaCO_3$ (Bohrmann et al., 1998). At the northern summit of the ridge (585 m water depth), decomposition of the gas hydrate supports a plume of methane extending at least 5 x 5 km and with methane concentrations >50,000 nl L^{-1}. The plume is fed by methane bubbles which rise from vent fields at the northern ridge segment. This plume was observed in July 1996 by video surveys from onboard the RV SONNE as well as by ROV-deployments using the ROPOS system. At the seafloor, gas vents support chemosynthetic communities which are typical of "cold seeps" at accretionary margins, along with large (100s of meters long; 1-5 m thick) calcium carbonate structures of highly varied morphology, mineralogy, and isotope composition. The fluids from the gas hydrate vents, sampled by ROPOS, are depleted in Cl and Mg by several percent compared to bottom water and are strongly enriched in methane (up to 400,000 nl L^{-1} CH_4). The composition of the exiting fluids clearly indicate active venting of a mixture of seawater, pore water, and fresh hydrate water. Composition of the "pore-fluid" end-member suggests that the fluids have been transported from below the BSR via high-permeability pathways (Suess et al., 1996). This is the first time that fresh water and methane gas from hydrate decomposition were observed to freely exit from vents.

2. CRUISE NARRATIVE AND STATION SUMMARY

Marta E. Torres

ROPOS (Remotely Operated Platform for Ocean Sciences) was loaded onto the R/V R. H. BROWN in Esquimalt, Victoria, on August 15th, 1998. BROWN moved to the Coast Guard Pier in Victoria on August 16th. It departed Victoria on August 18th at 1730 GMT; while in route to the Hydrate Ridge area, we conducted a CTD test cast and a ROPOS test dive at 44°22.4'N and 123°27.3'W. Upon arrival to the Hydrate Ridge area (19th Aug. 98, 2300 GMT), a preliminary Seabeam and 3.5 KHz survey was conducted to aid in locating optimal sites for transponder deployment (denoted as Station TFX98.00.SUR00; Table 1). The time and location of deployment is given in Section 6.2. To aid on calibration of the net, a sound velocity profile of the area was obtained by CTD deployments (TFX98.01.CTD01, TFX98.02.CTD02; see Section 4 for a description of the hydrocast program). The calibration was completed at 1430 GMT, on Aug 20th, but since ROPOS was not ready for deployment, we continued the geophysical survey of the area (TFX98.03.SUR01) and conducted another hydrocast (TXF98.04.CTD03). ROPOS was deployed at 1939 GMT on August 20th (see Section 6 for dive summaries). During this dive (TFX98.05.R454) we conducted a test of the manifold water sampler which indicated that this instrument had software problems, and no samples were collected. The dive was suspended due to air trapped in the new ROPOS tether, and ROPOS was returned to the ship at 2105 GMT. Upon retrieval new problems were identified with the submersible (motor to the pump was not operational); so, we repositioned the BROWN for another hydrocast (TFX98.06.CTD04), and for deployment of the Callenger Pump (TFX98.07.CP1; see Section 5). ROPOS was redeployed on the 21st of August from 0935 to 1630 GMT (TFX98.08.R455). While preparing for the next ROPOS dive, we conducted a CTD cast (TFX98.09.CTD05) and a Seabeam survey (TFX98.10.SUR02). The new dive (TFX98.11.R456), included the deployment of an elevator with several instruments. ROPOS was deployed on the 22nd of August at 0136 GMT. The elevator was released from the seafloor at 1920 GMT, and it was brought on board at 2000 GMT; unfortunately the instruments inside the elevator were lost during retrieval. The ROPOS dive continued to search for the lost instruments. One of the benthic barrels was found and recovered by ROPOS. Dive 456 ended on the 22nd of August at 2216 GMT. During ROPOS turn-around time we conducted another hydrocast (TFX98.12.CTD06). ROPOS was redeployed on the 23rd of August from 0122 to 1300 GMT (TXF98.13.R457). Several hours were spent looking for the lost barrel, while at the same time we conducted a video survey of the area and collected biologial specimens. A hydrocast station (TFX98.14.CTD07) was conducted during ROPOS turn-around time. ROPOS was re-deployed (TFX98.15.R458) at 1539 GMT on the 23rd of August. The dive ended at 2145 GMT, followed by the last hydrocast (TFX98.16.CTD08). The transponders used for navidation were released and recovered (TFX98.17) between 2317 GMT on the 23rd of August and 0145 GMT on the 24th of August. ROPOS was deployed for its final dive (TFX98.18.R459) at 0347 GMT on the 24th of August, and recovered at 0414 GMT because of telemetry loss from the ROV.

Because only five of the eight SIO flowmeters were deployed with ROPOS, the remaining three were deployed from the ship at the southern end of Hydrate Ridge (TFX98.18.FM.03; see section 6.4.2 for details). A 3.5 KHz survey was conducted in route to Newport, OR (TFX98.19.SUR3). The R/V BROWN docked at Newport at 1400 GMT on the 24th of August, 1998.

Table 1. Station summary

Station number	Position	Date	Water depth (m)	Section/ Appendix
TFX98.00.SUR.OO	Hydrate Ridge*	18/08/98		S:3
TFX98.01.CTD.01	44° 42.10 N, 125° 06.0 W	18/08/98	854	S:4/A:2&3
TFX98.02.CTD.02	44° 40.1 N, 125° 05.8 W	18/08/98	599	S:4/A:2&3
TFX98.03.SUR.01	Hydrate Ridge*	19/08/98		S:3
TFX98.04.CTD.03	44° 40.10 N, 125° 05.9 W	19/08/98	600	S:4/A:2&3
TFX98.05.R454	44° 40.20 N, 125° 05.7 W	19/08/98	600	S:6/A:4
TFX98.06.CTD.04	44° 40.20 N, 125° 05.83 W	20/08/98	610	S:4/A:2&3
TFX98.07.CP.01	44° 40.21 N, 125° 05.85 W	20/08/98	580	S:5
TFX98.08.R455	44° 40.18 N, 125° 05.89 W	20/08/98	586	S:4/A:2&3
TFX98.09.CTD.05	44° 40.20 N, 125° 05.89 W	20/08/98	603	S:4/A:2&3
TFX98.10.SUR.02	Hydrate Ridge*	20/08/98		S:3
TFX98.11.R456	44° 40.18 N, 125° 05.89 W	21/08/98	586	S:4/A:2&3
TFX98.12.CTD.06	44° 40.24 N, 125° 05.86 W	22/08/98	608	S:4/A:2&3
TFX98.13.R457	44° 40.24 N, 125° 05.80 W	23/08/98	610	S:6/A:4
TFX98.14.CTD.07	44° 40.19 N, 125° 05.91 W	23/08/98	606	S:4/A:2&3
TFX98.15.R458	44° 40.23 N, 125° 05.81 W	23/08/98	606	S:4/A:2&3
TFX98.16.CTD.08	44° 40.49 N, 125° 05.89 W	24/08/98	626	S:4/A:2&3
TFX98.17.NAV	44° 39.8 N, 125° 05.6 W	24/08/98	610	S:6.2
TFX98.18.R459	44° 40.32 N, 125° 05.81 W	24/08/98	590	S:4/A:2&3
TFX98.19.SUR.03	Hydrate Ridge*	24/08/98		S:3
TFX98.20.FM03	44°40.3 N, 125°05.8 W	24/08/98	600	S:6.4

*See Table 2

3. GEOPHYSICAL SURVEY

Anne Trehu

During TECFLUX98 we took advantage of "down time" for ROPOS to collect Seabeam 2100 swath bathymetry and Bathy 2000 3.5 kHz seismic data along selected tracks in the region of Hydrate Ridge. SEABEAM was also used to survey the ROPOS study area prior to installation of the acoustic transponder array.

The Seabeam data acquired during this cruise are shown in Figure 2 along with the ship track. Although the region had already been covered by multibeam data, acquisition of new data during this cruise provided a realtime view of the seafloor in the immediate vicinity of the seafloor sampling work. This survey also revealed the presence of a hill that was not evident in the paper copies of the bathymetric maps we had with us on board (Figure 2) and resulted in modification of the originally planned transponder array configuration. The hill is part of a NW-trending alignment of hills that cross the northern part of Hydrate Ridge. This structure is parallel to the trend of seafloor methane vents that were mapped during this cruise and by the R/V SONNE in 1996.

The new Seabeam data will also be useful for evaluating the quality of the new and existing data and for detecting possible changes in seafloor morphology. The new data will be compared to itself along overlapping tracks at different azimuths to determine the internal consistancy of the data. They will also be compared to the existing data for quality control and to determine whether any detectable change in seafloor topography has occurred since the previous survey. If justified by this comparison, the new data will replace the existing data in our working database.

The 3.5kHz data were collected with the objective of mapping pockets of sediment on Hydrate Ridge and to determine whether variations in low frequency seafloor reflectivity can be related to the amount and characteristics of hydrate. Several profiles also provide site survey information for a planned proposal to ODP. Examples of the data are shown in Figure 3. Amplitude as a function of time for each ping was saved on optical disk in SEGY format for further processing.

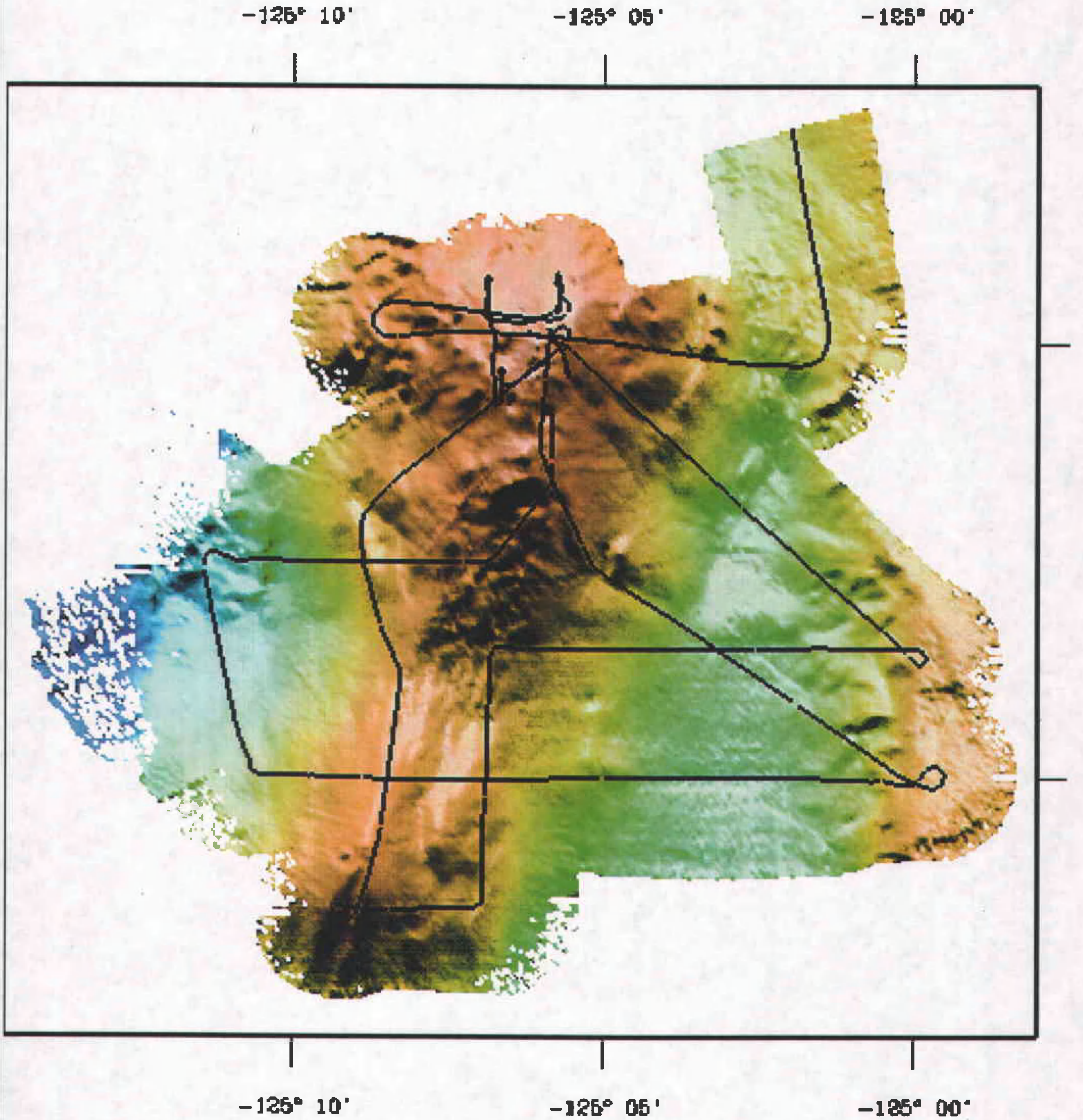
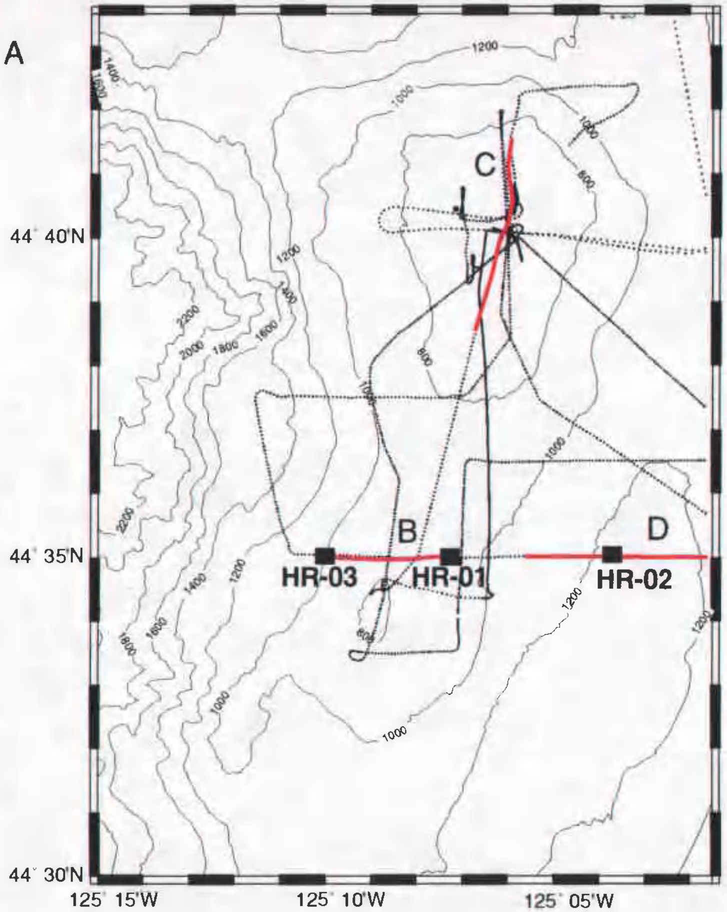
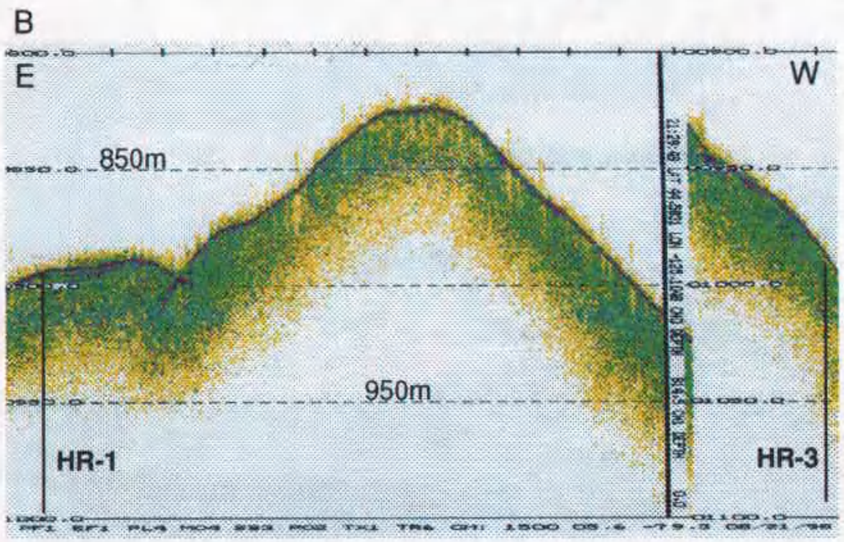
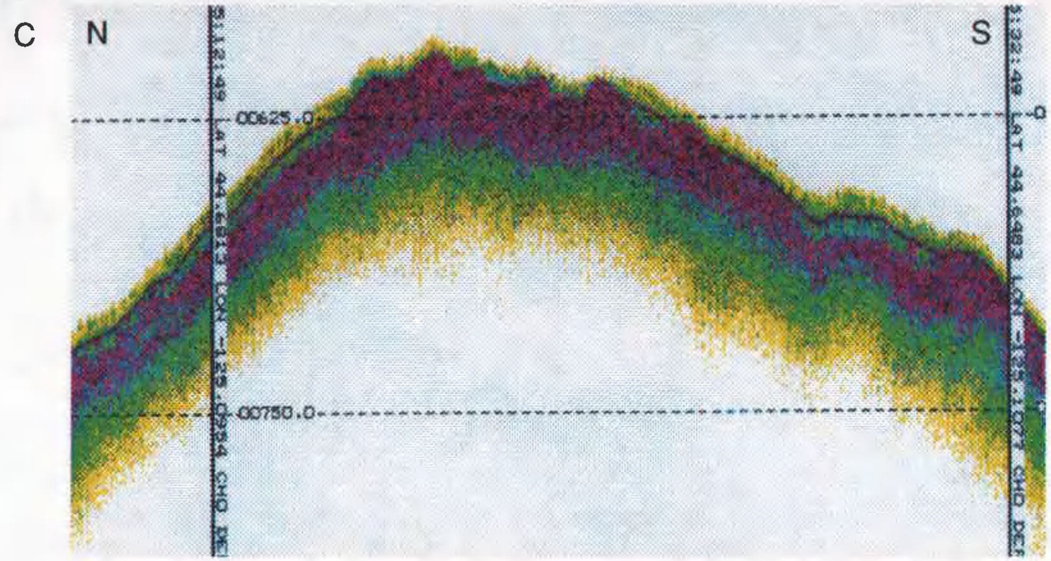


Figure 2. Multibeam bathymetry collected during the cruise. Tracklines are also shown. Depths range from 1800 m (dark blue) to 600 m (orange). Green is ~1200m. Yellow is ~1000m. Illumination is from the NW. Although this region was already covered by multibeam bathymetry, having these data collected on board was useful for placing the transponders for ROPOS navigation. These data also confirmed that features such as the apparent "mud volcano" SW of the southern crest of Hydrate Ridge is real and not an artifact of noisy data. This feature is the first evidence for seafloor venting recognized on the southern part of Hydrate Ridge. We also note a NW-trending alignment of hills along the western crest of Hydrate Ridge and anticlines at the base of the eastern flank of the ridge.







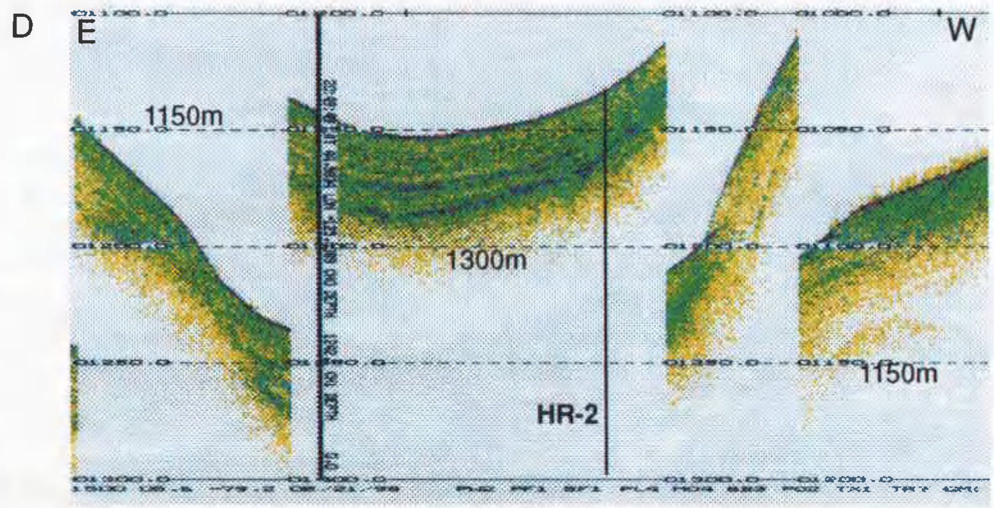


figure 4. Examples of 3.5 kHz data collected during August, 1998. These samples were scanned from paper records recorded during the cruise. Digital data are currently being processed. A shows tracklines along which Seabeam 2100 and digital 3.5 kHz data were collected. B is a crossing of the southern peak of Hydrate Ridge. C is a crossing of the northern peak of Hydrate Ridge. D is a crossing of the slope basin east of Hydrate Ridge. The locations of the data samples are shown by bold red lines. Acoustic energy penetrates up to 50 meters beneath the slope basin. The seafloor is a strong, but smooth, reflector on the southern peak of Hydrate Ridge. We attribute the long coda on the northern peak to scattering from a rough surface, as is observed, and infer that the smooth seafloor observed in camera tows over the southern peak is characteristic of the region, suggesting a favorable environment for drilling.

Table 2: Start and stop time of Seabeam2100 and Bathy2000 data acquisition.

STATION	START TIME day/hour/min	STOP TIME day/hour/min	NO. of KM	DATA FILES	COMMENTS
TFX98-0-SUR0	231/15/26	232/03/12		Y0819-03.sgy Y0819-04.sgy Y0819-05.sgy	survey during transit to dive sites and in the general region in preparation for transponder deployment.
TFX98-3-SUR1	232/13/03 paper 232/13/43 tape	232/17/36		Y0820-01.sgy	survey from dive site to follow MCS3 from 1989 ODP site survey and to cross MCS2.
TFX98-10-SUR2A	233/16/37	233/17/58		Y0821-01.sgy	at dive site.
TFX98-10-SUR2B	233/19/09	233/22/49		Y0821-02.sgy	survey from dive site to follow MCS2 from the the 1989 ODP site survey.
TFX98-19-SUR3	236/04/32	236/06/13		Y0824-01.sgy Y0824-02.sgy	NE/SW profile along the axis of Hydrate ridge.
TFX98-19-SUR4	236/08/30			Y0824-03.sgy	NS profile on east flank of southern part of Hydrate ridge.

4. WATER COLUMN SAMPLING

4.1 Hydrographic Program OSU Group
Robert Collier

During TFX98, we deployed 8 CTD casts and collected water from the 11 bottles mounted on the PMEL rosette (figure 4). The primary emphasis in station selection was to verify the location and characteristics of the primary gas input at the top of Hydrate Ridge. This location was also the target of nearly all the ROPOS dives.

Thus, most of the samples were clustered around the gas vents first seen on the Sonne cruise in 1996. Generally, the CTD's were deployed between the other activities related to the benthic program - primarily ROPOS deploments.

The CTD used was from Dr. E. Baker, NOAA PMEL (SBE model 911plus, with an SBE rosette and 20L nisking bottles). The CTD was also outfitted with a Benthose bottom separations between 0-100m, SeaTech 25cm beam transmissometer, and Seatech Nephelometer. Calibration data for the instruments are detailed in the seabird "*.con" files saved with each set of station data. For aquisition, we used the new Seabird Windows version of Seasave; for post processing we used the DOS Seasave versions 4.233. All data were plotted from the real-time cast (in Seasave) and were processed with Datcnv and Rossum to generate the bottle files listing the CTD properties for each sample. Only CTD1 was taken through the full Seabird-suggested post-processing path (including DATCNV, WILDEDIT, CELL, FILTER, SPLIT (downcast only), LOOPEDIT, BINAVG, and DERIVE. The CTD plots, the "bottle files", and the cast log with Niskin sample draw information are included in Appendix 2. All CTD data and ship logs during the CTD casts were taken off the ship and are available from Robert Collier (rcollier@oce.orst.edu).

Initially, a cast (TFX98.02.CTD1) was taken north of the ridge penetrating to 840m. This station was intended as a "background" cast. The remaining stations were focused directly on the vents near TVG-9-1 (SONNE leg 110-1a, 1996). The second cast (stn TFX98.02.CTD2) was targeted SSE of the Sonne station TVG 9-1 assuming that the currents might be from that direction. These two CTD profiles also were used to characterize the sound velocity through the water column necessary for the long-baseline navigation calculations. Casts 3-7 were collected within 100 meters of the vents observed during the ROPOS dives.

In general, the surface waters were very warm (16-17 degrees) with a shallow mixed layer. For the first half of the cruise (through TFX98.09) there was a pronounced subsurface nepheloid layer at 200m depth which we have previously attributed to a shelf-break origin. This layer appears to have elevated methane. By TFX98.12 (CTD6), the winds had come up at sea and this intermediate water feature disappeared for the balance of the stations. At several times, we positioned our casts to be "down stream" of the vents based on seafloor observations from the ROPOS pilots. At several

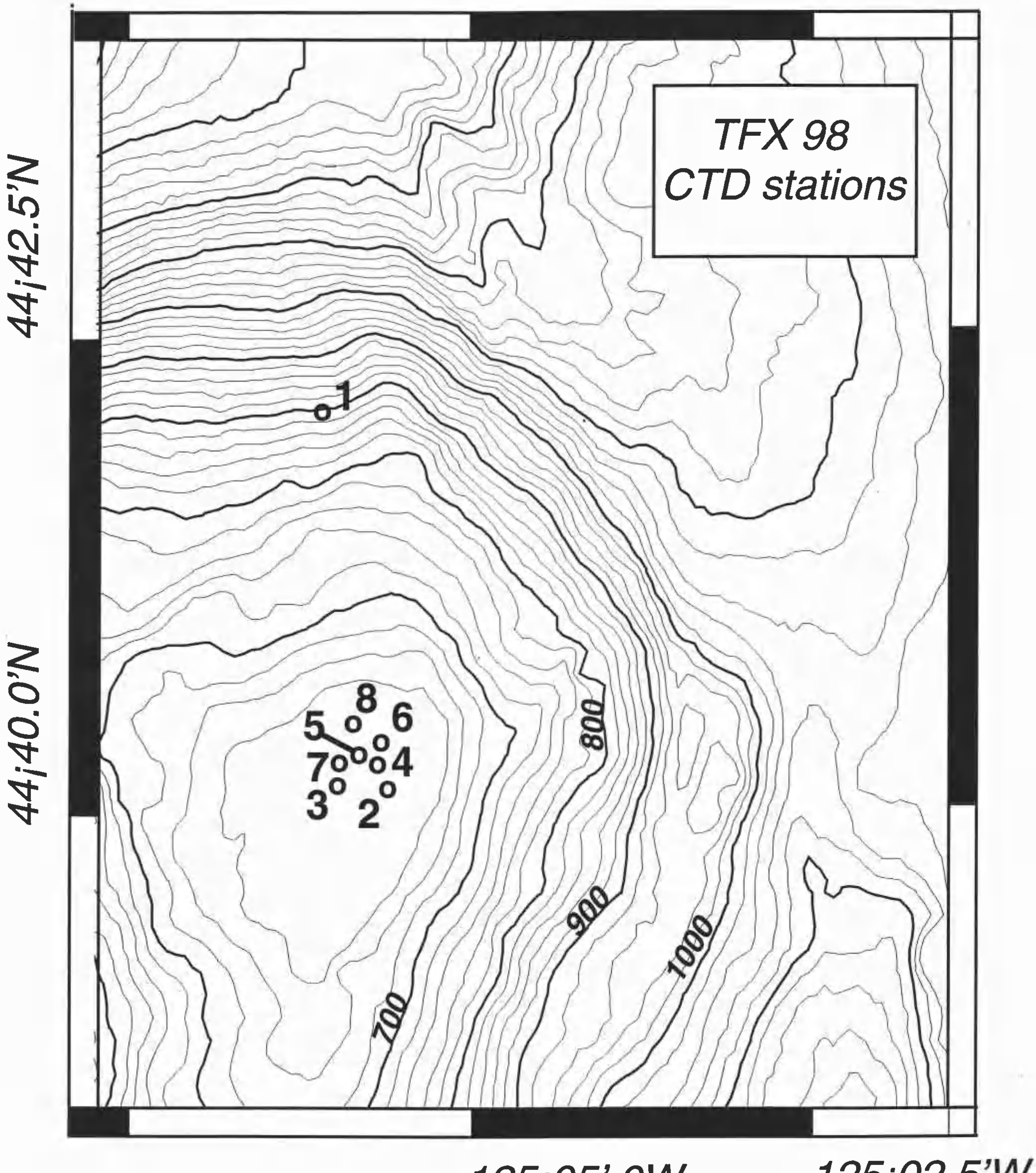


Figure 4. Location of hydrocast stations denoted CTD-01 to CTD-08 in Table 1.

times, the currents clearly switched from North to South (and back) suggesting fairly strong tidal components.

Samples collected from the rosette for shipboard analysis included methane; oxygen, total CO_2, and pH (Table 3). We also collected samples for He isotopes, nutrients, trace elements, salinity, carbon and oxygen isotopes, and methane oxidation rates. A detailed listing of the analysis planned (including analysts) is given in Appendix 3.

4.2 Total CO2 and oxygen analysis
Jim McManus and Chi Meredith

4.2.1 Analysis of total dissolved CO_2. A coulimetric system was set up for measuring CO_2 in seawater. The system consists of a KOH trap for CO2 and a coulometric reaction chamber. An ascarite trap was used to remove any CO2 that might be in the nitrogen coming from the tank to the mixing chamber; and a AgNO3 trap was used to remove any sulfides from the samples before they reach the reaction chamber. Final counts were recorded after 5 minutes. Several problems with the measurements occurred which need to be addressed before the next cruise:

1. The ascarite became moist, which changed the flow of nitrogen to the reaction chamber during the analytical runs, causing fluctuations in the counts. It was suggested that the ascarite may be unnecessary and could be removed from the system. This was not tried on this trip; however, the ascarite was changed daily.

2. The error in the standards increased over time, which indicated that the standard solutions may have been taking on CO_2 even though care was taken to keep them sealed when not being used. New unopened standards need to be used for each run.

3. The system needs to be running all the time to provide the necessary stabilization time prior to running the samples. During this trip, the machine was turned off and the gas flow stopped after each run.

Because of these difficulties, the precision of the method was 2%. Based on our experience we should be able to improve this precision by a factor of 10. Total dissolved CO2 was measured only for CTD.

Table 3. Methane, oxygen and total dissolved CO_2 in hydrocast stations.

Niskin bottle	Depth (m)	CH4 (nl/l)	O2 (ml/l)	TCO2 (mM)
CTD01				
1	838	56	0.249	
3	798		0.271	
5	750	54	0.264	
7	701	57	0.315	
9	651	49	0.408	
11	601	54	0.472	
13	551	38	0.579	
15	501		0.812	
17	452	101	1.032	
19	302	289	1.751	
21	213	373	2.063	
CTD02				
1	589	35	0.389	2.31
3	581	43	0.380	2.35
5	561	35	0.561	2.37
7	542		0.527	2.36
9	521	83	0.800	2.33
11	501	69	0.934	2.33
13	477	185	1.078	2.32
15	451	189	1.138	2.28
17	427	208		2.30
19	402	225	1.248	2.28
21	377	228	1.286	2.25
CTD03				
1	588	228	0.449	
3	575	65	0.503	
5	551	75	0.711	
7	526	43	0.783	
9	501	91	0.891	
9	501	89	0.905	
11	476	110	1.011	
13	451			
15	426	192	1.219	
17	401	268	1.314	
19	376	252	1.433	
19	376	257	1.438	
21	352	229	1.530	
CTD04				
1	591	129	0.483	
3	575	323	0.563	
5	550	4176	0.666	
7	525	322	0.741	
7	525		0.743	
9	500	112	0.859	
11	475	86	0.932	
13	450	136	1.081	
13	450		1.070	
15	425	160	1.148	
17	400	272	1.264	
19	350	202	1.625	
21	300	327	1.900	
	300		1.900	
	300		1.904	

Table 3 cont.

Niskin bottle	Depth (m)	CH4 (nl/l)	O2 (ml/l)	TCO2 (mM)
CTD05				
1	592	3462	0.504	
	592		0.492	
3	576	18108	0.763	
5	551	1129	0.663	
7	526	1085	0.760	
9	501	2746	0.884	
11	477	409	0.905	
13	451	1035	1.072	
15	426	2554	1.100	
17	402	2429	1.260	
19	377	548	1.445	
21	302	1228	2.090	
21	302		2.085	
21	302		2.089	
CTD06				
1	592	2536	0.464	2.30
1	592		0.482	
3	582	2106	0.454	2.31
5	571	1185	0.469	2.27
7	562	728	0.503	2.24
9	552	697	0.518	2.33
11	542	514	0.542	2.29
13	532	517	0.626	2.31
15	517	636	0.644	2.27
17	502	403	0.715	2.29
19	487	130	0.834	2.24
21	472	179	0.936	2.26
21	472		0.929	
CTD07				
1	450	386	1.265	
1	450		1.303	
3	420	212	1.357	
5	391	261	1.465	
7	362	248	1.562	
9	322	307	1.693	
9	322	301		
11	281	222	1.839	
13	242	143	2.074	
15	203	109	2.383	
17	143	106	2.778	
19	83	243	3.433	
21	2	138	4.625	
21	2		6.168	
21	2	139	6.208	
CTD08				
3	596	95	0.538	
3	596		0.551	
5	576	103	0.529	
7	556	98	0.555	
9	536	100	0.571	
9	536	101		
11	516	104	0.568	
13	496	105	0.654	
15	476	102		
17	457	107	0.973	
19	431	106	1.113	
21	406	108	1.266	
21	406	109	1.274	
21	406		1.271	

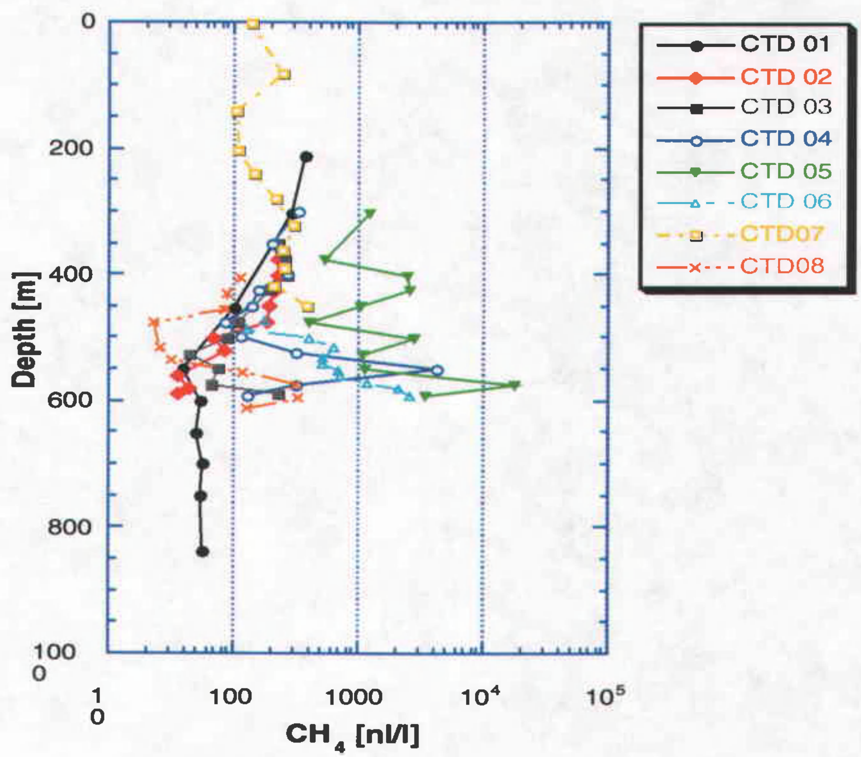


Figure 5. Methane distribution in the water column over Hydrate Ridge. The location of the CTS is given in Table 1 and illustrated in Figure 4.

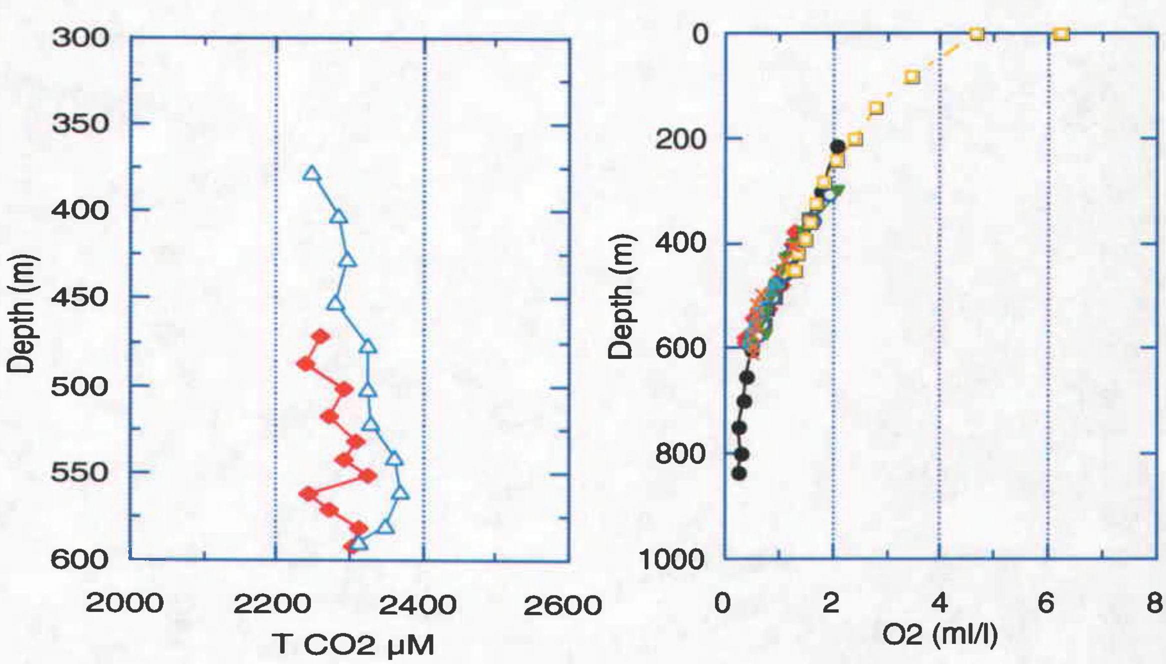


Figure 6. Total dissolved CO2 and ddissolved oxygen in the water column over Hydrate ridge. The symbols used are the same as those in Figure 5.

stations 2 and 6. The results are listed in Table 3, and illustrated in Figure 5.

4.2.2 Oxygen measurements. Dissolved oxygen was measured using the modified Winkler technique of Carpenter (1965); which has been fully automated. The results for the hydrocast stations is given in Table 3, and illustrated in Figure 5.

4.3 Methane analysis

Gregor Rehder and Katja Heeschen

4.3.1 Introduction. Methane concentrations in fluids resulting from dewatering of sediments on active continental margins are generally orders of magnitude larger than in seawater. The decomposition of methane hydrates, which are abundant in the research area of the TECFLUX98 expedition, also lead to enhanced CH4 concentrations in the water column. Recently, it has been argued that the destabilization of hydrates enhances fluid flow by adding fresh water from the hydrate to the fluid, increasing the buoyancy of the fluids. This process tends to augment the convergence generated overpressure and leads to local dewatering rates that are much higher than in the absence of hydrates (Suess et al., 1998)

On board analysis of methane in water samples is the fastest way to find evidence of fluid and/or gas sources on the seafloor and to trace the plume downstream. During Sonne cruise 110, enhanced CH_4 concentrations were traced up to a depth of 300m, apparently due to bubble transport through the water column. Hence, two different transport ways for methane in the water column -i.e advective transport of dissolved CH_4 as well as upwards migration due to bubble transport- determine the distribution of CH_4 in the research area. The $^{12}C/^{13}C$ ratio of the dissolved methane may help to define its sources. Additionally, the isotopic signature of CH_4 allows an estimate of the amount of CH_4 which has been oxidized, as microbial oxidation leads to isotopic fractionation.

4.3.2 Methods. Methane was measured on board using a modification of the vacuum degassing method described by Lammers and Suess, (1994). The modification involved sampling of 400ml of seawater using a large glass syringe and injecting into pre-evacuated 600 ml glass bottles. The air and water phases were equilibrated by shaking for at least 30 min. The gas phase was subsequently recompressed to atmospheric pressure and the CH_4 mole fraction of the extracted gas was determined from a 1ml subsample by FID gas chromatography. The total gas content of the sample was calculated from the measured dissolved oxygen concentration and assuming that N_2 and Argon were 100% saturated relative to their atmospheric partial pressures (Weiss, 1970). The methane content was calculated as the product of the mole fraction in the extracted gas phase and the amount of total gas (STP) in the sample. The remaining gas was transferred into evacuated 5ml Wheaton bottles and stored for shorebased analysis of the methane-carbon isotopic signature (CFMS).

4.3.3 Sampling. Samples for methane analysis were taken from all CTD hydrocasts at all depths. Some duplicates were sampled to check reproducibility of the measurements. For almost all of the samples, the extracted gas remaining after analysis of the CH_4 mole fraction was trapped and stored for isotopic analysis ashore (see sampling list). As the total gas content was comparatively low due to the very low oxygen content (see oxygen data), an underpressure remained in the vials. However, this should not affect sample quality.

4.3.4 Preliminary results. Except Station CTD 07, sampling at all hydrocasts focused on water depth greater than 300m (Table 3). The data is illustrated in Figure 6. Station CTD 01 was intended to serve as a background station to be compared with the stations on top of the northern summit of the second ridge (Hydrate Ridge). The CH4 concentrations from the bottom up to a depth of 550 m were found to be fairly constant, showing a background concentration of 50-60 nl/l. However, concentrations increased steadily to more than 350 nl/l at 200m depth. The sample at 213 m was taken right in the middle of a nepheloid layer. The general increase of CH4 in shallower water was also observed at hydrocast stations CTD 02, 03, and 04. The observed increase in CH4 concentrations above Hydrate Ridge might be caused by upward bubble transport of methane as suggested by Suess et al. (1998). However, the structure might be a less local phenomenon, as it was observed in at least four profiles.

A profile of the water column above 450m (CTD 07) revealed enhanced concentrations in the upper water column. CH4 at the 200 m level was 3 times lower at station CTD 07 than at station CTD 01, which seems to result from a change in the general flow pattern due to changing wind fields, which lead to the disappearance of the nepheolid layer observed during hydrocasts CTD 1-5. The surface water concentration (3 m depth, CTD 07) was found to be over-saturated relative to the ambient atmospheric partial pressure by about a factor of 2, an unexpected result, as open Pacific ocean surface waters are generally close to equilibrium with the atmosphere. Hence, the surface waters in the research area appear to be a source of atmospheric methane.

Plumes in the water column were most pronounced in the hydrocasts CTD 04 to 06, nearest to the active gas venting site found by ROPOS, where concentrations of up to 18000 nl/l were recorded. A high resolution profile of the plume was successfully sampled on CTD station CTD 06.

5. CHALLENGER PUMP

Chi Meredith

The Challenger *in situ* pump was deployed on 08/21/98 at 0305 at 44° 40.21' N and 125° 05.84' W. A pinger was attached to the cable above the pump to monitor the depth. We monitored the depth at approximately 580 meters, which placed the pump approximately 20 meters off the bottom. The timer on the pump was set for two hours and triggered the pumping cycle at approximately 140 meters from the bottom.

Upon recovery, the flow meter on the pump indicated that 32 liters of seawater had passed through the filter in two hours. The condition of the filter was good, and there was a great deal of brown-colored particles spread around its surface. The filter was removed, washed with de-ionized water to remove salts, dried in a desiccator, folded and placed in a petri dish to be analyzed in the lab later.

6. ROPOS OPERATIONS

6.1 Introduction

ROPOS (Remotely Operated Platform for Ocean Sciences) is a thirty/forty horsepower electro-hydraulic remotely-operated deep-submergence vehicle with complete sampling capabilities. It was designed and built by International Submarine Engineering. The ROPOS system consists of three major parts: deck unit, cage and ROV. The deck unit includes the winch, which hydraulics, power supply and consoles for remote operation of the vehicle. In deep water mode the vehicle is a component of a cage/vehicle system with full operational capability to 5000m depth. In this configuration, the vehicle and cage are deployed as a unit to the dive target depth. At depth, the vehicle operates independent of the cage with 300m of flying tether. In the deep mode ROPOS is a 30 Hp vehicle with an additional 10 hp available to cage systems. In shallow water mode, the vehicle "liveboats" or operates without the cage. In this configuration it routinely operates down to 350m depth as a 40 Hp vehicle. For the Hydrate Ridge program, the ROV was placed in its cage for launch and recovery.

The vehicle is equipped with two video cameras, two manipulators, sonar, a variety of custom sampling tools and several digital data channels. The vehicle and cage are normally navigated with an acoustic long baseline tracking system that is calibrated with differential or p-code GPS.

To date the vehicle has over 1100 hours of operation during 320 dives in shallow and deep modes. ROPOS has worked five seasons offshore in up to 5000 metres of water.

Table 4. ROPOS specifications during Tecflux 98 program:

General
Electro-hydraulic ROV.
30/40 hp electric motor.
2 fore-aft, 2 vertical, and 2 lateral hydraulic thrusters.
Vehicle dimensions: 2.6m x 1.7m x 1.45m
3000m depth capability
Caged system w/ 300m flying tether.
30Hp vehicle, 10Hp cage.
3500m electrical-optical cable mounted on a Hepburn winch

Cameras
Vehicle: 1) Sony DXC-950 three CCD, broadcast quality color NTSC camera with 16 x zoom; 2) Wide angle SIT low light NTSC camera.
Cage: One single-chip NTSC color camera.

Manipulators
One Kodiak (Magnum) seven function arm.
One five function arm.
Either arm can be fitted with small double-acting stainless steel jaws or 'Pac-man' (a clam sampler).
Both arms upgraded with hall-effect manipulator feedback sensors.
Will carry any tool with a standard 3/4 inch 'T' bar handle such as a rope cutters, snap hooks and core tubes.
Manipulators are very strong, rated for 600 lb. lift at full extension.

Sonar
Mesotech 971 scanning, color imaging sonar, modified with a lower frequency and narrow-beam head for enhanced long range response.

Sampling tools
Rotating sample tray has four separate compartments that can be subdivided.
Variable speed, reversible suction sampler capable of pumping 300 liters per minute gathers up to eight discreet, two liter samples. Filter sizes allow samples of bacteria through to large animals.
Hydraulically-actuated Lexan 'biobox' 80cm (long) x 30cm x 30cm (divisible).
Laser scales permit video record of specimen size and population density.
Falmouth Scientific 0-400 C temperature probe.

6.2 Navigation
Marta E. Torres

A long-baseline transponder net was established using the R/V BROWN P-code GPS navigation. Four transponders were deployed at the positions indicated in Table 5 and Figure 7; moored at approximately 125 m above the seafloor. Accurate sound velocities were obtained by two hydrocasts in the area. Calibration of the net, was conducted by towing an EDGETECH PS8000 deep-sea range meter. During calibration it was clear that one of the 4 transponder frequencies (ABS 1) did not respond to interrogation, and thus navigation for the ROPOS operation was conducted using only 3 transponders. During ROPOS deployment the EDGETECH PS8000 was transfered to the vehicle's cage and linked through the fiber optic cable with the onboard navigation PC and a DATASONICS transponder on the vehicle.

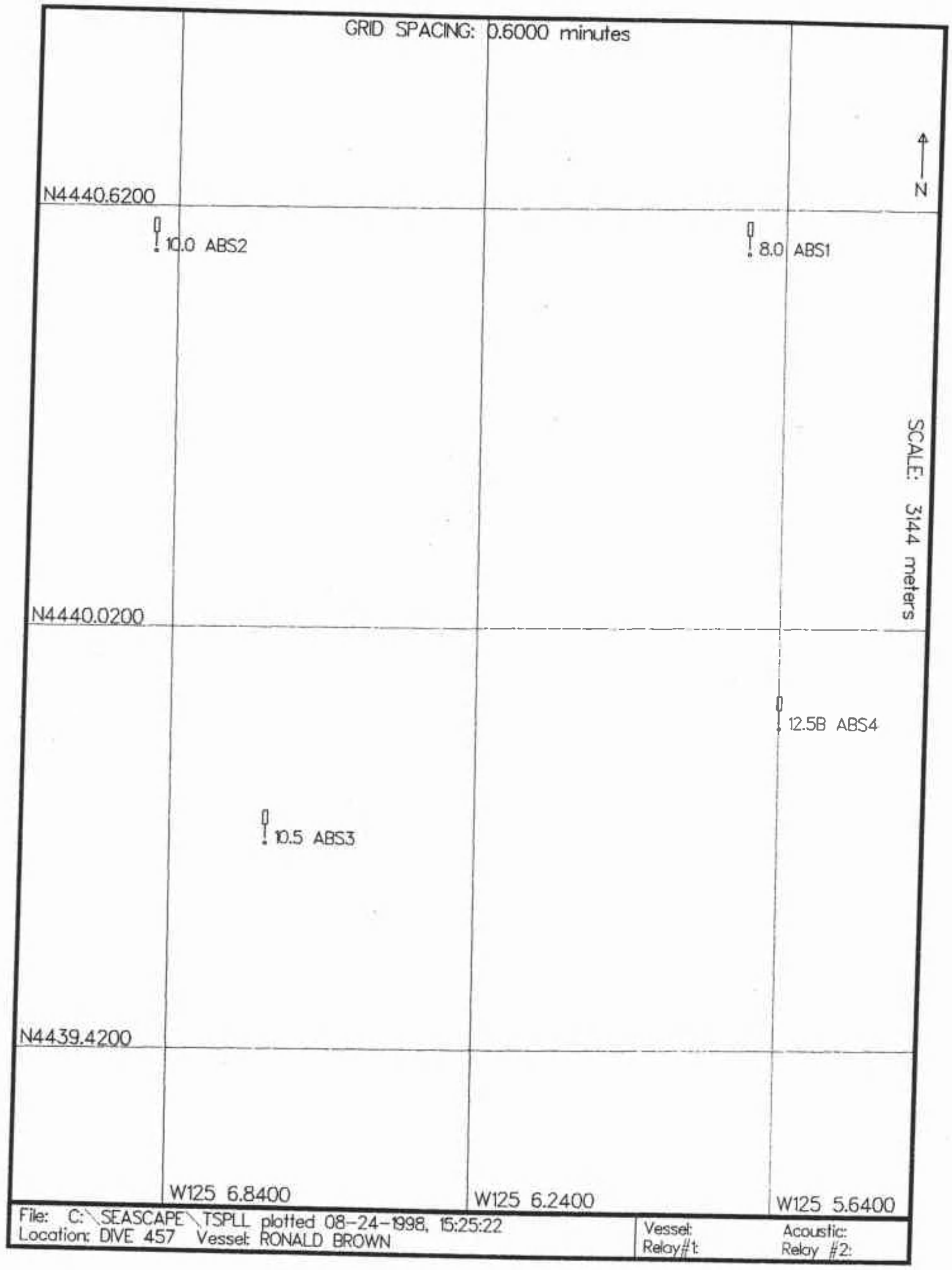


Figure 7. Location of the transponders used for ROPOS navigation.

Table 5. Position of transponders deployed on Hydrate Ridge

X-ponder ID	response frequency (KHz)	latitude 44 deg. N (min)	longitude 125 deg W (min)	water depth (m)
ABS1	8.0	40.5559	5.7128	632
ABS2	10.0	40.5552	6.8843	659
ABS3	10.5	39.7124	6.6524	640
ABS4	12.5	39.8785	5.6387	631

6.3 Dive summary

Marta E. Torres

Detailed logs of every dive were obtained onboard and are included in Appendix 4.

6.3.1 Dive 454 (TFX98.05)

Target: Hydrate Ridge, north summit.

Objectives: Test manifold sampler and survey the area.

Summary: Soon after ROPOS left the cage, the hydraulic pressure to the vehicle dropped due to air trapped in the new tether. Software problems were identified in the manifold fluid sampler. ROPOS did not reach the bottom, thus no seafloor survey was possible.

Upon retrieval, we decided to replace the manifold sampler with a benthic barrel. The suction sampler and still camera were installed. There were some new problems identified with the ROPOS motor which delayed re-deployment for approximately 9 hours.

6.3.2 Dive 455 (TFX98.08)

Target: Hydrate Ridge, north summit.

Objectives: Survey the area, deploy benthic barrel and collect bacterial mats and fluids with ROPOS suction sampler.

Summary: ROPOS was deployed approximately 200 meters east of presumed target, based on video tows obtained during the 1996 SONNE cruise 110-1a. The seafloor there is paved by carbonates with extensive clam fields. It is noteworthy that there were lots of dead clams, and only few live specimens were observed. As we traveled westward, several bacterial mats were encountered. At 44°40.1816'N and 125°05.8854'W we observed intense bubbling at discrete vents within the seafloor. The benthic barrel was deployed in this area, but the gas discharge was too large for this sampler, so it was moved to a site next to the vents. During the 2-hour deployment of the barrel, we collected fluids, sediments, bacterial mats and a few clams with ROPOS suction sampler. During this period, the gas discharge was intense. We observed 4 distinct conduits within a 4m^2 area. After retrieval of the benthic barrel, ROPOS moved up the water column, following the bubble trace. Bubbles were observed from the seafloor (586 m) up to a depth of 526 m!

6.3.3 Dive 456 (TFX98.11)

Target: Hydrate Ridge, north summit.

Objectives: To deploy a wide variety of benthic instruments using an elevator, and to collect gas, fluids and biological samples.

Summary: Using ROPOS elevator system, we carried to the seafloor 2 benthic barrels, 3 SIO flowmeters, 4 gas samplers, and a strobe beacon to aid in locating the sampling sites during the various trips planned to and from the elevator. The strobe was extremely useful in reducing the amount of time needed to find the sampling site; it was left as a marker on the active vent site.

One of the SIO flowmeters was lost during deployment of the elevator. However, soon after ROPOS reached the bottom, it was found, retrieved and deployed within a clam field. The remainder flowmeters were also deployed within the clam colony to obtain data on the spatial variability of this type of active site.

Next, we deployed two of the gas samplers over one of the active gas-discharge sites. In one of the deployments a small white deposit was observed within the gas sampler, which we believe was a gas-hydrate precipitate. While attempting to collect a third sample over another bubbling site, the gas hydrate precipitation on the still camera was intense enough to block the view of the site. Unfortunately the third gas sampler was clogged by either bacterial mats which were resuspended or by sediment particles (sulfides?) and no sample was collected. Two barrels were deployed during this dive. One of them over the clam field, next to the SIO samplers and the other next to the active gas-discharge site. Bacterial samples and bottom water were also collected with ROPOS suction sampler. Before commencing the clam sampling for growth experiments, the elevator was released with the aim of recovering the gas samplers and benthic barrels well ahead of the next dive. The elevator cleared the surface successfully, with all the equipment in it. Unfortunately, both barrels and a gas sampler were lost during retrieval of the elevator. Thus, we delayed the clam sampling program to search for the lost equipment. One of the barrels was found on the seafloor after searching for about 1 hour. It was retrieved and brought back to the ship, concluding this ROPOS dive.

6.3.4 Dive 457 (TFX98.13)

Target: Hydrate Ridge, north summit.

Objectives: To look for the lost equipment and collect clams for the growth experiment.

Summary: During the search for the lost benthic barrel and gas sampler, a detailed survey of the area was also conducted. A second area of gas discharge was documented during the barrel search, this site lies in a line trending 111 degrees relative to the first gas discharge site. The area of gas discharge mapped during the SONNE cruise in 1996, also lies within this band of active ebullition; which suggests that the gas discharge is restricted to this narrow zone. This feature parallels larger mounds imaged by Seabeam as well as larger structures of the accretionary prism such as the Daisy bank. The area of intense bubbling is characterized by the presence of extensive bacterial mats. Large clam fields were observed to occur ten's of meters away from the gas seeps. A third province with carbonate blocks but no clams or bacterial mats was mapped for approximately 200 meters away from the seeps. After approximately 8 hours of search, the benthic barrel #2, was not found, but the gas sampler was recovered. We the abandoned the search and proceeded to collect live clams for the clam growth experiment. Clams were collected from two different fields and brought back to the surface for size determination, and tagging.

6.3.5 Dive 458 (TFX98.15)

Target: Hydrate Ridge, north summit.

Objectives: To implant the tagged clams in a corral for growth experiments, and to deploy two additional SIO flowmeters.

Summary: ROPOS was re-deployed within 2 hours, to maximize the chance for the clams to stay alive. A clam corral was deployed at a clam field and the tagged clams were implanted within the corral. During this dive, two SIO flowmeters were brought to the bottom and deployed next to the clam corral.

We then traveled to the active seep site, in an attempt to obtain better gas flow measurements over the seeps. When the site was reached, it was clear that the discharge rate had decreased tremendously. Of the 4 discharge conduits previously observed, only one was active and the ebullition was much reduced: clearly a time-dependent system.

The dive was then concluded, to allow time for a final dive to re-test the manifold sampler and the down-looking sonar. The navigation transponders were released and all four were recovered.

6.3.6 Dive 459 (TFX98.17)

Target: Hydrate Ridge, north summit.

Objectives: To test the manifold sampler and down-looking sonar.

Summary: The manifold sampler had software difficulties which were identified during dive 454. It was not clear whether the system was operational in conjunction with the

ROPOS telemetry system. The down-looking sonar (Imagenix), was supposed to be installed in ROPOS and tested prior to the cruise; however, the installation was not completed and it was unclear during the entire leg, as to how much time was required to make the system operational. It was not ready for deployment during this dive either. ROPOS was deployed but after a few minutes it lost telemetry completely and the dive had to be terminated.

6.4 Sampling devices

6.4.1 Benthic barrel from OSU group

Marta Torres, Bill Rugh and Dale Hubbard

The OSU benthic barrel is a cylindrical chamber with a large opening at the bottom and a small opening at the top. The barrel is designed to sample sites that have active fluid flow, by placing the barrel over a vent site thereby channeling the effluent from the seafloor into a semiclosed environment (Figure 8). The bottom of the barrel is open and can be pushed into the sediments to assure a seal over the vent sites. The internal volume of the barrel is initially flooded with ambient seawater and is slowly replaced by venting fluids. Six Niskin water bottles (2 L) are mounted vertically around a cylindrical polycarbonate frame, and they are tripped sequentially by a motor located in the center of the frame. Changes in the concentration of dissolved components in the sequentially timed water samples are then used to calculate their flux rates (Carson et al., 1990). The exhaust port at the top of the chamber carries a thermistor flowmeter which directly records the flow rate from the chamber. A description of this instrument and its operation can be found in Linke et al., 1994.

6.4.2 Flow meters from SIO group

Kevin Brown and Michael Tryon

The SIO flux meters were configured for this cruise with the specific purpose of measuring surface aqueous fluxes that occur at slow to intermediate rates (i.e. minimum rates of ~ 0.1 mm/y and maximum rates a few 1000 mm/y). These meters were deployed by ROV to examine the general nature of the heterogeneous pattern of diffuse flow around the main seep sites. The meter is illustrated in

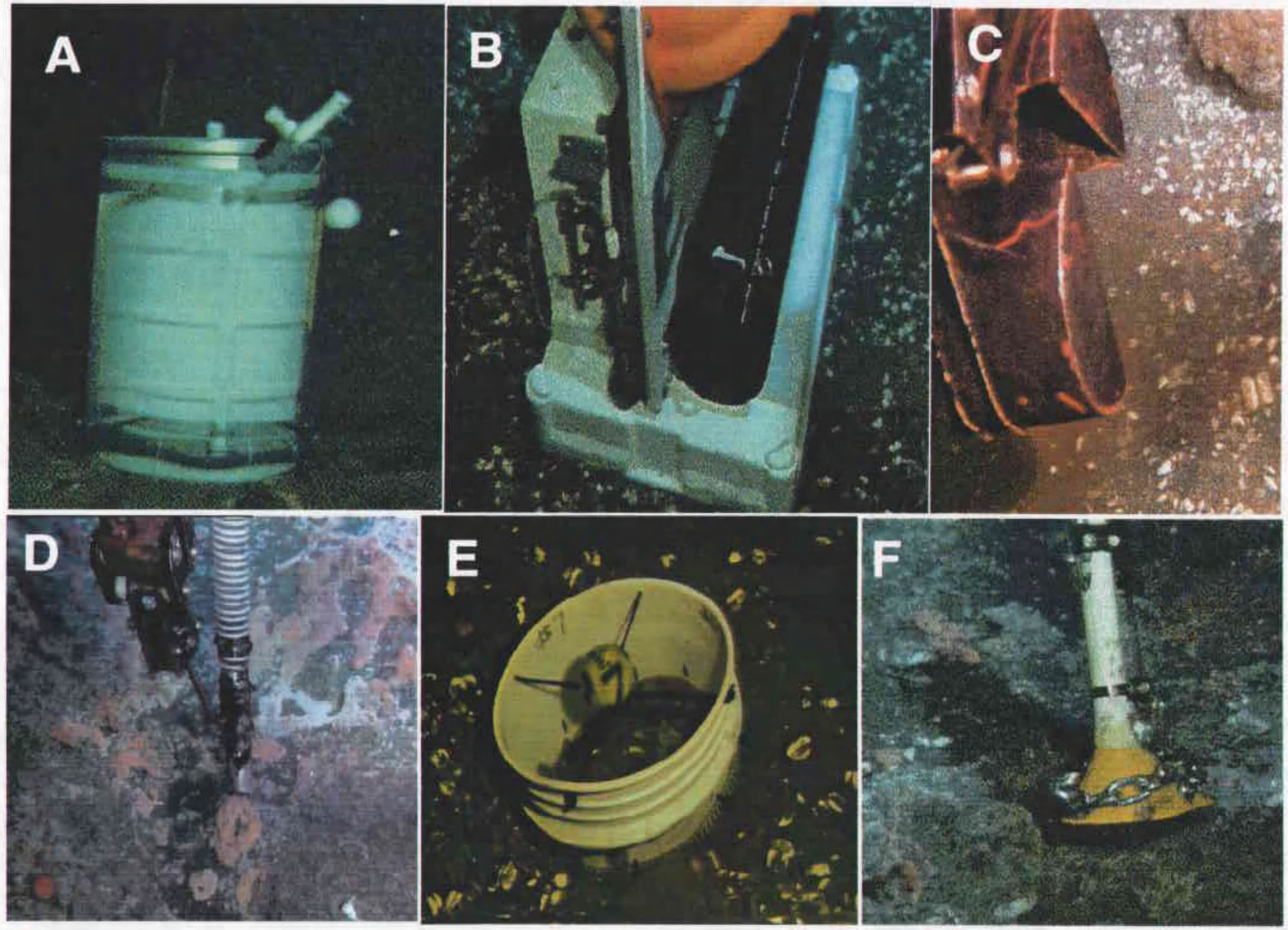


Figure 8. Images illustrating the various tools and instruments used during TECFLUX 98. A. OSU Benthic Barrel; B. SIO Flow Meter; C. ROPOS Pac-Man claw used to collect live clams; D. Suction sampler used to collect bacterial mats, sediments and venting fluids; E. MBARI's Clam corral emplaced at the seafloor for clam growth experiments; F. USC gas sampler positioned over an active gas seep.

Figure 8 and described in Figure 9 (Brown, et al., 1995). The Br- tracer dilution method has proven to be very robust in terms of the tracer's conservative nature. The use of the Br- tracer will also allow the measurement of other major dissolved chemical constituents and nutrients to be undertaken where appropriate.

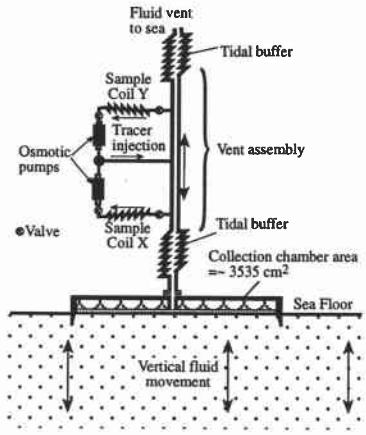


Figure 9. Schematic figure showing the basic geometry of the flux meter. Within the WGF-meter a chemical tracer is injected by the osmotic pumps into the water stream as it moves through the outlet tubing. The osmotic pumps also simultaneously samples the labeled fluids on either side of the injection point by continuously drawing a portion of the labeled fluids into the sample coils. The flux rate is determined from the relative tracer concentrations in the two sample coils. Upper coil = Y, lower coil = X. Both flow into and out of the sediment can be measured

During TECFLUX 98 eight SIO Flux Meters were deployed, five on and around seep sites and three onto non-seep sites. On ROPOS dive 456 flux meters E, F, and G were deployed at a seep site located at 44° 40.203 N by 125° 05.867 W at approximately 0700 GMT on 8/22/98 (Figure 8). Meter E was deployed upon moderately sparse clam coverage near the edge of the site. Meter F was deployed upon dense clam coverage and white bacterial mats. Meter G was equipped with gas sampling capabilities and was also situated upon dense clam coverage and white bacterial mats. On ROPOS dive 458 flux meters A and C were deployed at a small seep site located at 44° 40.244 N by 125° 05.804 W at 1800 GMT on 8/23/98. Both were situated upon moderate density clam beds without apparent bacterial mats. This is also location of the clam corral reported in Section 6.8. Flux meters B, D, and H were deployed from the surface and allowed to settle to the bottom. They were located along a 200m transect from 44° 34.52 N by 125° 08.77 W bearing 109°. This site shows a strong BSR but no apparent vent/seep sites and no carbonate pavement. Meter H is equipped for gas sampling and was deployed at the ridge top end point (44° 34.52 N by 125° 08.77 W). Meters B and D were set up for very low flux rates and were deployed at 44° 34.50 N by 125° 08.70 W and 44° 34.48 N by 125° 08.63 W respectively. The flux meters are equipped with acoustic releases and will be recovered in late September, during a Wecoma cruise to the area.

6.4.3 ROPOS suction samplers
ROPOS Team

ROPOS is equipped with a variable speed, reversible suction sampler capable of pumping 300 liters per minute. This sampling device gathers up to eight discreet, two-liter samples. Different filter sizes can be outfitted to the sampling bottles to allow for collection of various types of fauna ranging from bacteria through to large animals. Fluid and sediment samples can also collected with this device.

6.4.4 Gas Samplers from USC group
Doug Hammond and Steven Colbert

For sampling the free gas at the methane seeps, a series of four samplers were designed and built by the USC group. They consist of a funnel connected through a PVC pipe to a gas-collection chamber (Figure 8). The performance of the new gas samplers was adequate. Three deployments were made. The first 2 instruments did a good job in collecting samples from a very rapidly-flowing gas seep. Based on visual estimates of the stream of bubbles and the rate at which the funnel on the bottom of the collector filled, it may have had a flow rate of 5 liters/minute (with an estimated uncertainty of a factor of 3). The third collector was deployed at another seep and clogged quickly, without obtaining a sample. During recovery, one valve on the first sample was cracked, causing the sample to become contaminated with air during the draw procedure, but analysis of sequential aliquots during the draw produced a very consistent ratio of Rn/CH4 (Sections 6.6.1 and 6.6.3). The second sample was knocked off the elevator, sank to the sea floor, and was recovered on a subsequent dive. Despite this disturbance, the Rn/CH4 ratio in the sample was very similar to the first sample. The basic design of the collector appears good, but the samplers and the mounting rack must be made much more durable.

6.5 Camera Survey
Marta Torres

A detailed survey of the seafloor revealed that the seeps line up within a narrow band trending 111 degrees (Figure 10). This feature approximately parallels larger mounds imaged by Seabeam (Figure 2) as well as strike-slip faults of the accretionary prism such as the Wecoma and Daisy Bank faults (Goldfinger et al., 1996). These transverse strike-slip faults and associated folds cross the plate boundary and continue beneath the accretionary wedge to the continental shelf. These faults extend to the basaltic basement of the subducting Juan de Fuca plate (Goldfinger et al., 1992, Goldfinger et al., 1996). The observation that the gas seeps show the same WNW bearing as these faults suggests that the mechanisms for gas transport and discharge in Hydrate Ridge may be tied to the structural behavior of the margin.

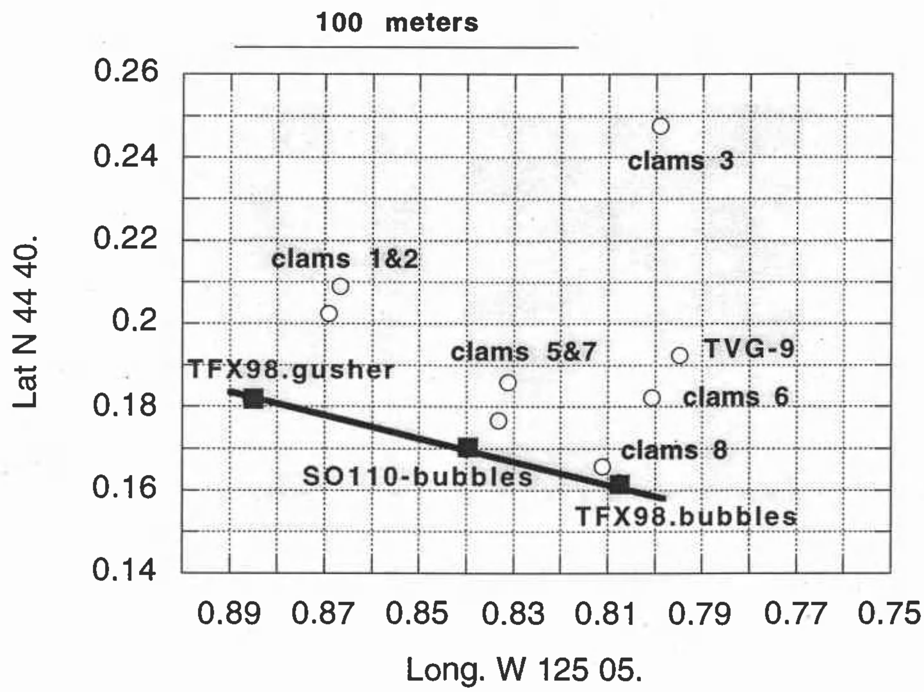


Figure 10. Location of the active seep areas (closed squares), and clam sites (open circles) in the surveyed area (light gray box). TVG-9 denotes the location of a TV-guided grab collected during SO110; the scarp left by the grab was still clear in the seafloor. SO110-bubbles denotes the location of the active seep site imaged by the Explos towed camera1996 survey.

The sites of gas discharge along the active province are highly focused within conduits with an approximate cross-sectional area of 5 cm^2 (Figures 11 A and B). Visual observations indicate that the gas discharge is highly episodic; the gas flow during the periods of intense bubbling was estimated to be in the order of 5 liters/minute. The area of active bubbling is characterized by the presence of extensive bacterial mats (Figure 11C). Large clam fields (Figure 11 E) were observed ten's of meters away from the gas seeps, and are

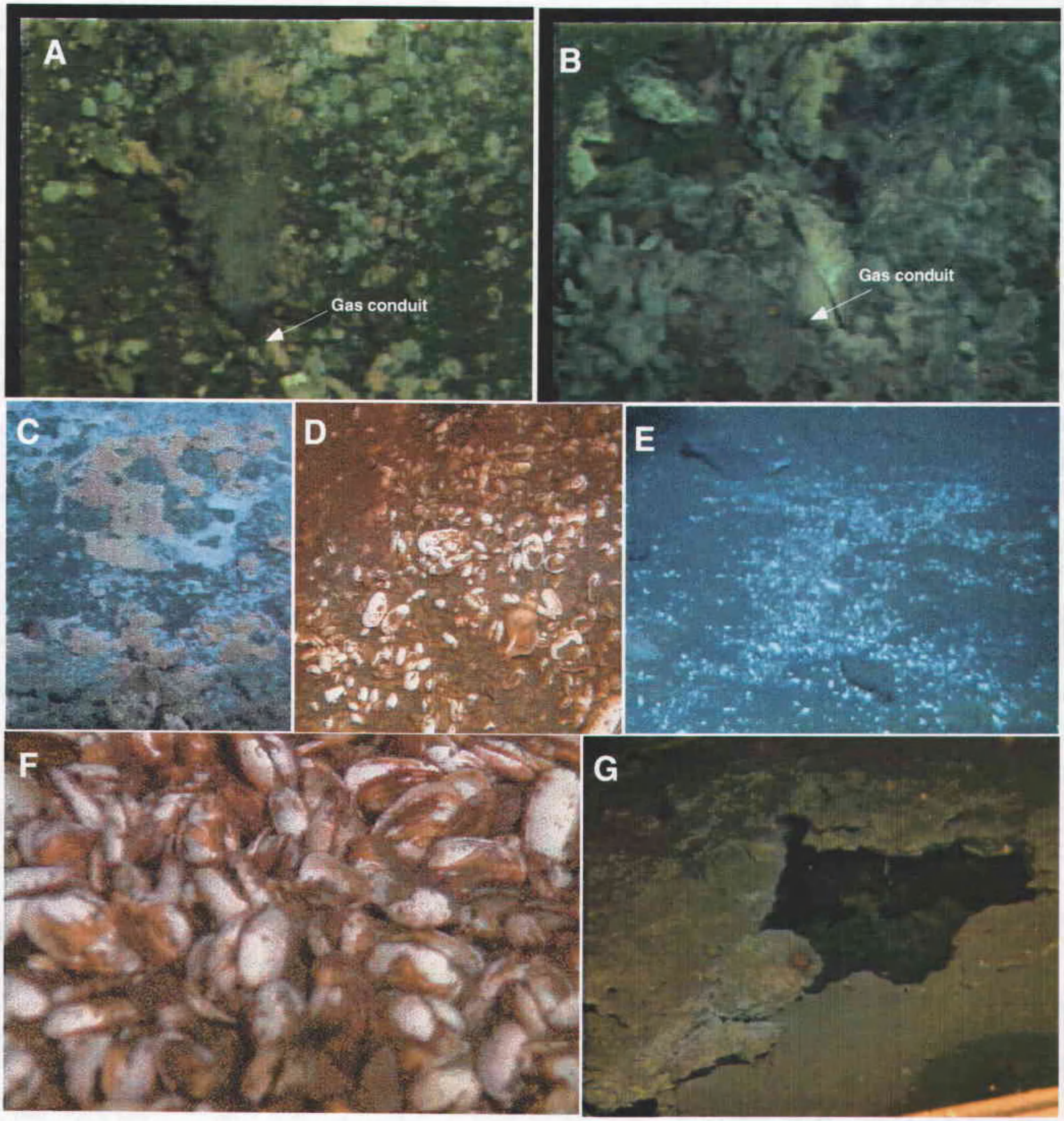


Figure 11. Examples of various characteristics of the three provinces identified during the camera survey. A and B illustrate the active seeps, where episodic gas discharge occurs within discreet conduits with an approximate cross sectional area of 5 cm2. C. Shows bacterial mats characteristic of areas of active seepeage. D and E. illustrate clam fields which occur tens of meters away from the active seeps (Figure 10), and are characterized by predominance of dead clam.s. F. shows the isolated clam field (clam 3, Fig 10) within the carbonate province(G.).

characterized by a predominance of dead clams, with small pockets of live specimens. A third province with extensive coverage of carbonate blocks (Figure 11G) but no clams or bacterial mats was mapped for approximately 200 metes away from the seeps (Figure 10). The only exception in this carbonate province is one small clam field (clam 3 in Fig 10), which, in contrast with the large fields of mostly dead clams mapped close to the gas seeps, is characterized by having a predominance of live individuals (Figure 11 F). The characteristics of clam field 3 suggest that it is a younger field.

6.6 Water and gas chemistry

Samples collected with the benthic barrel and the gas samplers were analyzed on board for their methane, oxygen, radon, total CO_2, sulfide and ammonium contents. Sub-samples from these as well as from the ROPOS suction samplers were taken for further shore-based analysis. The sample distribution is given in Appendix 5.

6.6.1 Methane analysis (Geomar group)

Gregor Rehder and Katja Heeschen

Samples were taken from the OSU benthic barrel deployments 1 and 3 (BB1, BB3) as well as from the USC bubble gas sampler for methane analysis, as described in section 4.3.2. All of the samples were highly oversaturated at atmospheric pressure, leading to degassing out of the Niskin bottles before and during sampling. Degassing of the water collected with the benthic barrel BB1 resulted in volumes of up to 68 ml of gas (STP) out of a 400 ml water sample. Because of degassing, the gas contents derived from the barrel samples are surely lower than the *in situ* concentrations. The gas contains about 88 % of methane; and although highest gas concentrations were detected in bottles 5 and 6 of the barrel, a time series trend can hardly be derived from the results. However, the barrel gas samples will enable the determination of the isotopic composition of CH_4 before being introduced into the water column, where this isotopic fingerprint is subsequently altered due to oxidation.

6.6.2 Total dissolved CO_2 and oxygen measurements

Jim McManus and Chi Meredith

Samples were taken from the benthic barrel for measurements of total dissolved CO_2 and oxygen, using the techniques described in section 4.2. As with the case of methane, accurate measurements of these gasses were hindered by the active degassing of the water samples in the Niskin bottles. Bubbles formed in the sampling syringes prior CO_2 analysis: a 1/4" space of gas formed in the syringe from degassing. The samples were measured within 8 hours of sampling, and the space in the syringe was purged before loading the sample into the coulometric set-up. Results are given in Table 6.

Table 6: Concentration of total dissolved CO_2 and oxygen in the Benthic Barrel samples, Station TFX98.08.R455.BB1

Time since engagement (minutes)	TCO2 (mM)	O2 (ml/l)
10	2.31	0.629
23	2.38	0.823
37	2.42	0.857
61	2.40	0.518
85	2.45	0.253
111	2.41	0.097

6.6.3 Radon measurements

Doug Hammond and Steven Colbert

The objective of this effort was to explore the use of Rn-222 as a tracer of methane dynamics in a hydrate system. We hoped to determine the concentration of Rn in gas bubbles emanating from the sea floor, the concentration in fluids exiting the sediment, and the Rn emanation rate from solids in the vicinity of the vents. As part of our efforts, we utilized a newly designed device for sampling gases bubbling from the sea floor (Section 6.4.4). We obtained two *in situ* gas samples, fluids collected from the OSU benthic barrels, and some solids recovered with clam specimens (Section 6.8).

6.6.3.1 Barrel Samples. Results from the OSU barrels are listed in Table 7. The second barrel failed to function properly, tripping on deck and drawing surface water (see Section 6.6.2). These samples provide upper limits for any blank in our analytical system and demonstrate that it must be small. The first barrel indicates a consistent increase in concentration with time. Samples of the head space gas were drawn after the bottle was nearly drained and indicate that gas bubbles that formed in the samplers during recovery removed some dissolved gases from the samples. We have not yet attempted to correct our measurements for this effect. When these measurements are coupled with data on flow rates and barrel volume, we may be able to estimate the Rn in fluids entering the barrel. An additional complication is that the barrel also received some gas bubble streams, and this may have introduced a significant fraction of the radon increase.

6.6.3.2 Gas Seep Measurements. The results from the gas samples were quite interesting, as the Rn/CH_4 ratio was very high, approximately 50 dpm/liter (stp) CH_4. If this ratio is used to calculate the Rn concentration in pore fluids that should be in equilibrium with this gas phase, the Rn should be about 1.5 dpm/cc of pore fluid. This concentration is comparable to that in groundwaters of granitic bedrock and suggests the gas must be derived from a region with high (solid)/(gas + water). While the plumbing of the gas flow is unknown, the high flow rate of the sampled seep suggests a very short transit time from the gas source (presumably the base of the BSR at 70 mbsf) to the sea floor. If plumbing acts as a straight pipe with cross-sectional area of 5 cm^2 (a rough estimate of the orifice area emitting the sampled gas), approximately 1 hour should be required to flow 70 m at the seepage rate estimated above. We plan to obtain material from ODP to estimate Rn emanation rate from solids at the depths of the BSR zone, and with this information, we hope to estimate the solid/gas ratio in the zone producing methane. Of course, alternative interpretations may be possible, and we hope to explore these. For example, if methane is forming hydrates as it rises from the source zone and Rn is excluded from the hydrate structure, the gas could be enriched in Rn as it rises. We plan laboratory experiments to see if Rn and CH4 are fractionated during hydrate formation.

6.6.3.3 Plans for future field work. In addition to solid phase analyses and experiments noted above, we plan to:

1. Improve the durability and ease of handling of the gas sampler.
2. Attempt to directly sample fluid flow and measure Rn concentration. This can provide information about the solid/fluid ratio and residence times of fluids in the units transmitting flow; Rn alone cannot separate the influence of these two effects.
3. Obtain additional gas samples to see if relationships exist between flow rate and Rn concentration that may permit estimates of transit times and/or variability in solid/gas ratios in seep source areas.

Table 7. Analyses from Benthic Barrel Niskins

ID	Coll date	time	Rn	Rn sig (dpm/L)	Notes
BB1-2	8/21/98	6:42	7.55	0.55	
BB1-2head	8/21/98	6:42	0.53	0.32	needs corr. for matrix
BB1-4	8/21/98	7:20	25.75	1.29	
BB1-4head	8/21/98	7:20	2.42	0.46	needs corr. for matrix
BB1-6	8/21/98	8:10	30.30	1.25	
BB1-6head	8/21/98	8:10	8.80	0.68	needs corr. for matrix
BB2-5	8/21/98	17:00	0.28	0.71	
BB2-2	8/21/98	17:00	0.35	0.35	eff and bkg for 32
BB2-6	8/21/98	17:00	0.29	0.72	eff for 31

Table 8. Analyses from gas samplers. All need counting gas matrix correction. Methane data courtesy of GEOMAR. Methane analyses for GS2 have not yet been run, but this sampler is assumed to have not leaked.

ID	Coll date	time	Rn	Rn sig (dpm/L)	CH4	Rn/CH4 (dpm/L)
GS1-0	8/22/98	3:55	43.60	1.57	0.86	51
GS1-1	8/22/98	3:55	36.79	1.41	0.60	61
GS1-2	8/22/98	3:55	18.46	0.90	0.36	51
GS1-3	8/22/98	3:55	8.86	0.69	(0.12)	(74)
GS2-0	8/22/98	4:45	44.11	2.15	(1.00)	(44)
GS2-1	8/22/98	4:45	45.24	2.12	(1.00)	(45)

Correction of BB-1 for degassing during recovery

Assume that: 1)only water was lost and this water degassed to the extent of that sampled; 2) there was no gas exchange during draw; and 3) Niskin was essentially empty when head space was sampled.

- Vn=Niskin volume
- Vg=gas volume in Niskin when recovered
- C' = dissolved gas conc in sample before degassing
- C = dissolved gas conc measured
- Cg = conc of gas in gas phase after degassing but before draw
- Cgm = conc of gas measured in head space after Niskin is empty
- B = Cg/C at equilibrium = dimensionless Henry's Law constant

Conservation of mass says:

$$C'Vn = CVn + CgVg$$
$$CgVg = CgmVn$$

Then for Rn

$$C'Vn = CVn + CgmVn$$
$$C' = C + Cgm$$

Note that we can use Rn to find

$$Vg/Vn = Cgm/(BCn)$$

For any other gas,

$$C'/C = 1 + BVg/Vn = 1 + (B/Bradon)(Rn)gm/(Rn)$$

These corrections for methane relative to Rn would be about (Bmethane)/(Bradon) = 10

Niskin	(Rn)gm/(Rn)	C'/C for Rn	C'/C for methane
2	0.070	1.070	1.7
4	0.94	1.094	1.9
6	0.29	1.290	3.9

Note that the Rn gas phase measurements have not yet been corrected for counting matrix effects.

6.6.4 Ammonium and sulfide analysis (OSU group)

Jim McManus, Marta Torres, and Richard Kovar

The ammonium and sulfide analyses were conducted immediately after sample retrieval, using standard spectrophotometric techniques (Grasshoff, 1976). The results are given in Table 9. Although the concentration data for the other gases measured in these samples suffered from severe degassing of the water during retrieval and sampling, the sulfide and ammonium data is affected to a much lesser degree by degassing, due to their speciation in seawater. The distribution in the benthic barrels with time is illustrated in Figure 12. This distribution is consistent with a period (app. 40 minutes) during which the ammonium and sulfide released at the vents are consumed by dissolved oxygen, after which the concentrations of these reduced species are observed to increase. This pattern was first described by Suess et al. (1998) who estimated the oxygen consumption -due to oxidation of reduced species associated with venting- to be more than 4 orders of magnitude greater than that normally found at the sea floor at comparable ocean depths.

Table 9: Concentration of dissolved sulfides and ammonium in the Benthic Barrel samples, Station TFX98.08.R455.BB1

Niskin Pos.	local time	min	H2S (uM)	NH3 (uM)
	6:19	00		(0.98)*
1	6:29	10	06.58	
2	6:42	23	03.55	1.09
3	6:56	37	09.89	1.02
4	7:20	61	23.08	2.19
5	7:44	85	40.21	2.78
6	8:10	111	42.14	2.66

*value from bottom water

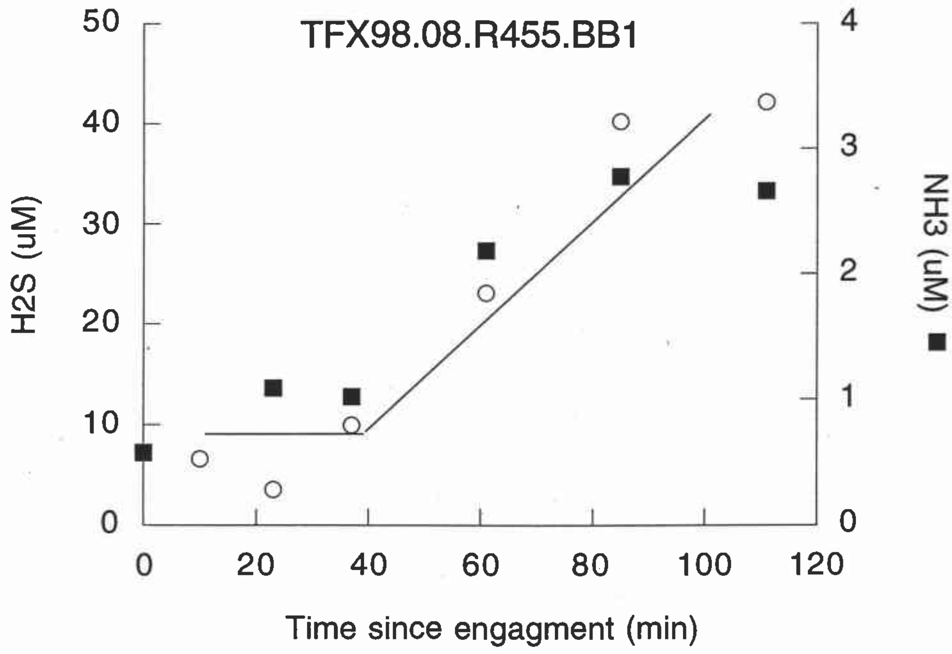


Figure 12. Ammonium (solid squares) and sulfide (circles) concentration in bottles tripped during a 2-hour deployment of the benthic barrel in Station TFX98.08.R455.BB1.

6.7 Microbiology program

The main objectives of the microbiology program of Tecflux 98 were:

1) To determine the specific oxidation rates of methane near the plume origin at the seep sites, and to evaluate whether the methanotroph biomass changes down plume as the stock and specific enzyme activity increase; and

2) To study microbial ecology of the seeps, with special enphasis on the community and diversity of microbial populations in unusual habitats. These systems will be compared with hydrothermal vents and other cold-seep localities.

6.7.1 Methane oxidation studies

Marie de Angelis -HSU

The objective of methane oxidation experiments is to evaluate the possibility that the hydrate systems support a rich population of methanotrophs at the interface which can "seed" the methane plume. These methanotrophs may be capable of removing a significant amount of CH_4 by microbial oxidation. To this efffect, a total of 60 water samples were obtained from benthic barrel and CTD water column casts for CH_4 oxidation. Samples were subsampled into glass septum vials and sealed without a headspace and injected with seawater which had been previously equilibrated with $^{14}CH_4$. Samples were incubated at 4.2°C for various periods ranging from 0 to 8 hours, before being killed with 6N NaOH. Samples were then transferred to 20-ml poly-sealed caps for analysis onshore. Samples will be treated with 6N H_2 SO_4 to convert all oxidized $^{14}CH_4$ to $^{14}CO_2$ which will be collected on β-phenethylamine soaked filters and counted on a liquid scintillation counter (LSC). All treated samples will also be filtered through 0.2 μm filters and counted on the LSC to determine incorporation of oxidized $^{14}CH_4$ into ^{14}C cell carbon.

6.7.2 Microbial ecology program

Craig L. Moyer – WWU

Samples were taken in order to examine the molecular microbial ecology through a study of community structure and diversity. Slurp gun samples, including microbial mats, sediments, and sea water were collected from an area approximately 1 m^2 surrounding the most active methane venting area found by ROPOS. These will be used as the basis for enrichment culture selection, lipid analysis, and subjected to nucleic acid extraction and further molecular biological study.

From ROPOS Dive # 455, slurp gun buckets #2 through #6 and #8 were used to collect microbiology samples:

(1) Five 1ml subsamples of microbial mats were fixed in 2.5% EM grade glutaraldehyde for subsequent examination with SEM, TEM and with FISH (fluorescent in situ staining hybridization). These were then moved to 4EC for storage and transfer.

(2) Five 1ml subsamples of microbial mats were quick frozen in liquid nitrogen using 40% glycerol as a cryopreservative to be used for subsequent enrichment culturing techniques. These were then moved to -80EC for storage and transfer.

(3) Two subsamples of microbial mats (approx. 25cc each) were transferred to 50ml centrifuge tubes and maintained at 4EC also to be used for subsequent enrichment culturing techniques.

(4) Five subsamples of microbial mats (approx. 35cc each) were transferred to 50ml centrifuge tubes and quick frozen in liquid nitrogen to be used for future nucleic acid extractions. These were then moved to -80EC for storage and transfer.

(5) Four subsamples of sediments (approx. 35cc each) were transferred to 50ml centrifuge tubes and quick frozen in liquid nitrogen to be used for future nucleic acid extractions. These were then moved to -80EC for storage and transfer.

(6) Several scale worms (polychaetes) found in the mats were transferred to a single 50ml centrifuge tube and quick frozen in liquid nitrogen to be used for future examinations. These were then moved to -80EC for storage and transfer.

(7) Several snails found in the mats were also transferred to a single 50ml centrifuge tube and quick frozen in liquid nitrogen to be used for examinations. These were then moved to -80EC for storage and transfer.

From ROPOS Dive # 456, slurp gun buckets #2 through #7 were used to collect microbiology samples. Due the need for expedient turn around of the sample buckets, samples were pooled prior to processing.

(1) Three subsamples of microbial mats (approx. 35cc each) were transferred to 50ml centrifuge tubes and quick frozen in liquid nitrogen to be used for future nucleic acid extractions. These were then moved to -80EC for storage and transfer.

(2) Three subsamples of sediments (approx. 35cc each) were transferred to 50ml centrifuge tubes and quick frozen in liquid nitrogen to be used for future nucleic acid extractions. These were then moved to -80EC for storage and transfer.

(3) Several snails found in the mats were also transferred to a single 50ml centrifuge tube and quick frozen in liquid nitrogen to be used for examinations. These were then moved to -80EC for storage and transfer.

(4) Several scale worms (polychaetes) found in the mats were transferred to a single 15ml centrifuge tube and were fixed in 2.5% EM grade glutaraldehyde for subsequent examination with SEM, TEM and with FISH. These were then moved to 4EC for storage and transfer.

(5) Several snails were found in the mats were also transferred to two 15ml centrifuge tubes and were fixed in 2.5% EM grade glutaraldehyde for subsequent examination with SEM, TEM and with FISH. These were then moved to 4EC for storage and transfer.

6.8 Clam growth experiments

Patrick J. Whaling - M.B.A.R.I.

At Station TFX98.08.R455, near the gas seeps, we collected 2 live clams (*c. pacifica*) and 2 dead clams (1 *c. pacifica* and 1 *c. kilmeri*) with the suction sampler. Live clams were frozen for later gonad studies. At Station TFX98.13.R47 we collected 120 live clams (*c. pacifica*) of which 44 were tagged and returned to the bottom into a clam corral at 599 m at clam site #3 (Figures 8,10 and 11). 70 clams collected live were frozen for gonad and other studies; 6 clams went to Carl Katsu for High school project. A couple hundred dead clam-shells will be measured for size distribution studies. 3 polychates were preserved for $C^{14/13}$ measurements.

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APPENDICES

Appendix 1: BROWN (RB-98-03-Leg 2A) Marine Operations Abstracts.

Appendix 2: Hydrographic Data.

Appendix 3: Sample listings for hydrographic stations.

Appendix 4: Detailed ROPOS logs for Dives 454 to 459.

Appendix 5: Sample distribution for materials collected during ROPOS dives.

Appendix 6: Cruise Participants.

Appendix 7: Addresses of participating research institutes.

Appendix 8: Abstract submitted to AGU Fall meeting, 1998.

Appendix 1
Marine Operations Abstracts

APPENDIX 1- BROWN (RB-98-03-LEG2A) MARINE OPERATIONS ABSTRACTS SUMMARY

day/mo/yr	Time (GMT)	Latitude	Longitude	Operation Description or Remarks
18/08/98	1730	48°24.4	123°24.2	depart Victoria, Canada
18/08/98	1919	48°22.4	123°26.9	test CTD in water
18/08/98	1942	48°22.4	123°26.9	CTD on deck
18/08/98	2330	48°22.4	123°27.3	ROPOS test dive
18/08/98	0105	48°22.3	123°27.4	underway for project site
19/08/98	2330	44°42.3	125°01.9	seabeam survey
20/08/98	0105	44°40.53	125°05.72	T1 deployed
20/08/98	0140	44°40.48	125°06.87	T2 deployed
20/08/98	0215	44°39.63	125°06.67	T3 deployed
20/08/98	0246	44°39.87	125°05.62	T4 deployed
20/08/98	0403	44°41.99	125°06.00	TFX98.01.CTD01 CTD deployed at station #1
20/08/98	0456	44°42.00	125°06.00	CTD @ surface
20/08/98	0538	44°40.1	125°05.8	TFX98.02.CTD02 CTD station #2
20/08/98	0632	44°40.12	125°05.82	CTD on deck
20/08/98	0700	44°40.1	125°05.8	Hove to for hydrophone deployment
20/08/98	0854	44°40.1	125°05.8	start tow
20/08/98	0933	44°40.3	125°05.6	passing "C4"
20/08/98	1000	44°39.8	125°06.1	passing "C3"
20/08/98	1025	44°40.1	125°06.7	passing "C2"
20/08/98	1051	44°40.6	125°06.1	passing "C1"
20/08/98	1115	44°40.3	125°05.5	end tow
20/08/98	1500	44°33.5	125°08.4	TFX98.03 seabeam survey
20/08/98	1747	44°40.2	125°05.9	on sta TFX98.04.CTD03 CTD in the water
20/08/98	1900	44°40.2	125°05.7	setting up for ROPOS station TFX98.05.R454
20/08/98	2035	44°40.2	125°05.7	dive suspended, recovering ROPOS for maintenance
20/08/98	2105	44°40.2	125°05.7	ROPOS on deck
21/08/98	0115	44°40.2	125°05.8	TFX98.06.CTD 4 CTD deployed
21/08/98	0153	44°40.2	125°05.8	CTD on deck
21/08/98	0300	44°40.2	125°05.8	Challenger pump deployed TXF98.07.CP1
21/08/98	0700	44°40.19	125°05.72	on station for ROPOS dive site, awaiting deployment
21/08/98	0935	44°40.19	125°05.72	ROPOS in the water TFX98.08.R455
21/08/98	1635	44°40.18	125°05.87	ROPOS at surface
21/08/98	1643	44°40.18	125°05.87	ROPOS on deck
21/08/98	1806	44°40.15	125°05.92	CTD at surface TFX98.09 CTD5
21/08/98	1857	44°40.15	125°05.92	CTD on deck
21/08/98	1925	44°40.1	125°05.9	enroute to seabeam survey TFX98.10.SUR02
21/08/98	1941	44°38.8	125°06.0	on survey TFX98-10, passing "A"
21/08/98	1955	44°37.4	125°05.2	passing Pt. "B"

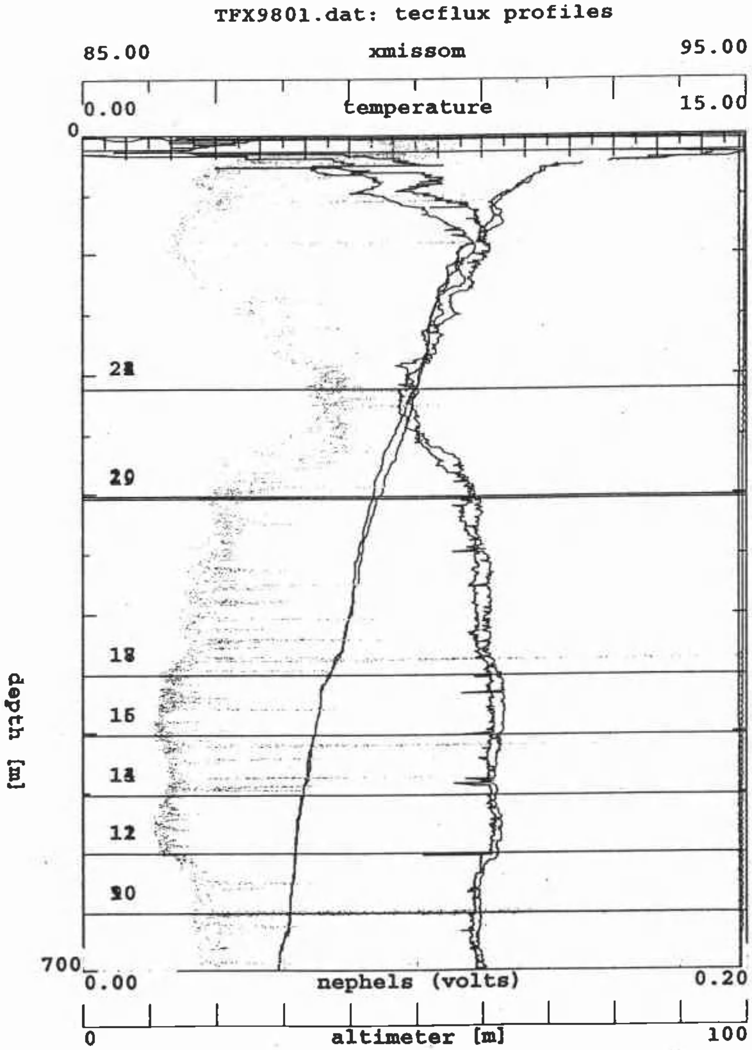
21/08/98	2035	44°34.9	125°00.0	passing Pt. "C"
21/08/98	2136	44°35.1	125°10.6	passing Pt. "D"
21/08/98	2158	44°3735	125°11.4	passing Pt. "E"
21/08/98	2225	44°37.5	125°07.0	passing Pt. "F"
21/08/98	2236	44°38.4	125°05.9	passing "G"
21/22/08/98	2330	44°40.2	125°05.8	on ROPOS site - awaiting dive- station TFX98.11.R456
21/22/08/98	0137	44°40.193	125°05.888	elevator deployed
22/08/98	0520	44°40.208	125°05.891	ROPOS on deck
22/08/98	1100	44°40.206	125°05.886	on ROPOS dive
22/08/98	1915	44°40.189	125°05.861	Pos'n move for recovery of elevator
22/08/98	1920	44°40.188	125°05.860	elevator released
22/08/98	1933	44°40.17	125°05.86	elevator sighted @ surface
22/08/98	2000	44°40.17	125°05.82	elevator aboard w/o instruments which floated loose and sank
22/08/98	2015	44°40.16	125°05.81	on station for search w/ ROPOS
22/08/98	2124	44°40.21	125°05.80	on sta for recovery of lost barrel
22/08/98	2216	44°40.20	125°05.82	ROPOS on deck
22/08/98	2234	44°40.24	125°05.88	on CTD site TFX98.12. CTD6
22/23/08/98	2332	44°40.24	125°05.88	CTD on deck
22/23/08/98	0000	44°40.24	125°05.81	on station awaiting ROPOS
22/23/08/98	0122	44°40.240	125°05.804	ROPOS deployed TFX98.13.R457
23/08/98	1315	44°40.244	125°05.841	ROPOS on deck
23/08/98	1346	44°40.238	125°05.899	TFX98.14 CTD7 CTD deployed
23/08/98	1425	44°40.16	125°06.02	CTD on deck
23/08/98	1539	44°40.254	125°05.800	on station for dive TFX98.15.R458
23/08/98	2145	44°40.252	125°05.810	ROPOS on deck
23/08/98	2200	44°40.251	125°05.795	enroute to TFX98.16
23/08/98	2211	44°40.49	125°05.90	TFX98.16 CTD08 CTD in the water
23/08/98	2252	44°40.49	125°05.89	CTD at depth 613 m
23/24/08/98	2317	44°39.81	125°05.6	xducer in water
23/24/08/98	2336	44°39.8	125°05.6	xponder #1 released- station TFX98.17
23/24/08/98	0027	44°39.7	125°06.6	xponder #2 released
23/24/08/98	0145	44°40.5	125°06.9	xponder #3 released
23/24/08/98	0347	44°40.501	125°05.733	ROPOS deployed-station TFX98-18-R459
23/24/08/98	0414	44°41.3	125°04.7	ROPOS recovered
24/08/98	0700	44°34.49	125°08.76	approaching flowmeter deployment #1
24/08/98	0709	44°34.533	125°08.775	Flowmeter #1 deployed
24/08/98	0724	44°34.513	125°08.690	Flowmeter #2 deployed
24/08/98	0739	44°34.488	125°08.622	Flowmeter #3 deployed
24/08/98	0809	44°34.61	125°08.38	enroute to 3.5 Khz survey line-TFX98.19.SUR03
24/08/98	0830	44°34.5	125°06.3	start survey @ 2.5 kts
24/08/98	0900	44°35.9	125°06.3	continue survey @ 2.5 kts
24/08/98	1025	44°40.1	125°06.3	c/c for Newport, 1/5
24/08/98	1400	44°35.8	124°10.1	end of cruise

Appendix 2
Hydrographic Data

```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\CTDdata\TFX9801.dat
* Software Version 5.0
* Temperature SN = 32111
* Conductivity SN = 394
* Number of Bytes Per Scan = 30
* Number of Voltage Words = 4
* System UpLoad Time = Aug 20 1998 04:05:03
* Ship:       NOAA R/V Ronald Brown
* Cruise:     TFX98
* Station:    TFX98-01-CTD1
* Latitude:   44 42.0N
* Longitude:  125 06.0W
# interval = seconds: 0.0416667
# start_time = Aug 20 1998 04:05:03
# sensor 0 = Frequency  0  temperature, primary, 32111, 09-Jul-1998
# sensor 1 = Frequency  1  conductivity, primary, 394, 09-Jul-1998, cpcor = -
9.5700e-08
# sensor 2 = Frequency  2  pressure, 22003, 22-Jul-1997
# sensor 3 = Frequency  3  temperature, secondary, 646, 09-Jul-1998
# sensor 4 = Frequency  4  conductivity, secondary, cpcor = -9.5700e-08
# sensor 5 = Extrnl Volt  1  nephelometer (IFREMER), measured voltage
# sensor 6 = Extrnl Volt  3  userpoly 0
# sensor 7 = Extrnl Volt  5  altimeter
# sensor 8 = Extrnl Volt  7  transmissometer, 1001d, factory
# datcnv_date = Aug 20 1998 05:02:32, 4.233
# datcnv_in = TFX9801.DAT TFX9801.CON
# rossum_date = Aug 20 1998 10:29:50, 4.233
# rossum_in = TFX9801.ROS TFX9801.CON
```

Bottle Position	Date Time	DepS	T068	Sal	Sigma-é00	Potemp068	
1	Aug 20 1998	837.845	4.0726	34.3212	27.2453	4.0093	(avg)
	04:28:05	0.056	0.0004	0.0005	0.0004	0.0004	(sdev)
3	Aug 20 1998	798.370	4.1851	34.2982	27.2150	4.1244	(avg)
	04:30:55	0.059	0.0005	0.0004	0.0004	0.0005	(sdev)
5	Aug 20 1998	749.501	4.2494	34.2842	27.1968	4.1923	(avg)
	04:32:58	0.050	0.0009	0.0005	0.0005	0.0009	(sdev)
7	Aug 20 1998	700.946	4.3839	34.2548	27.1588	4.3301	(avg)
	04:34:36	0.163	0.0054	0.0019	0.0020	0.0054	(sdev)
9	Aug 20 1998	650.514	4.6429	34.2005	27.0873	4.5919	(avg)
	04:36:28	0.164	0.0002	0.0002	0.0002	0.0002	(sdev)
11	Aug 20 1998	600.885	4.7731	34.1659	27.0451	4.7257	(avg)
	04:38:09	0.090	0.0009	0.0005	0.0005	0.0009	(sdev)
13	Aug 20 1998	551.195	4.9565	34.1368	27.0010	4.9125	(avg)
	04:39:54	0.173	0.0007	0.0003	0.0003	0.0007	(sdev)
15	Aug 20 1998	501.407	5.2177	34.0952	26.9376	5.1768	(avg)
	04:41:41	0.103	0.0020	0.0004	0.0005	0.0019	(sdev)
17	Aug 20 1998	451.510	5.5594	34.0799	26.8847	5.5216	(avg)
	04:43:28	0.089	0.0006	0.0004	0.0003	0.0006	(sdev)
19	Aug 20 1998	302.365	6.5577	34.0282	26.7166	6.5304	(avg)
	04:47:04	0.083	0.0003	0.0003	0.0002	0.0003	(sdev)
21	Aug 20 1998	213.057	7.5087	33.9808	26.5480	7.4880	(avg)
	04:49:33	0.098	0.0007	0.0002	0.0002	0.0007	(sdev)

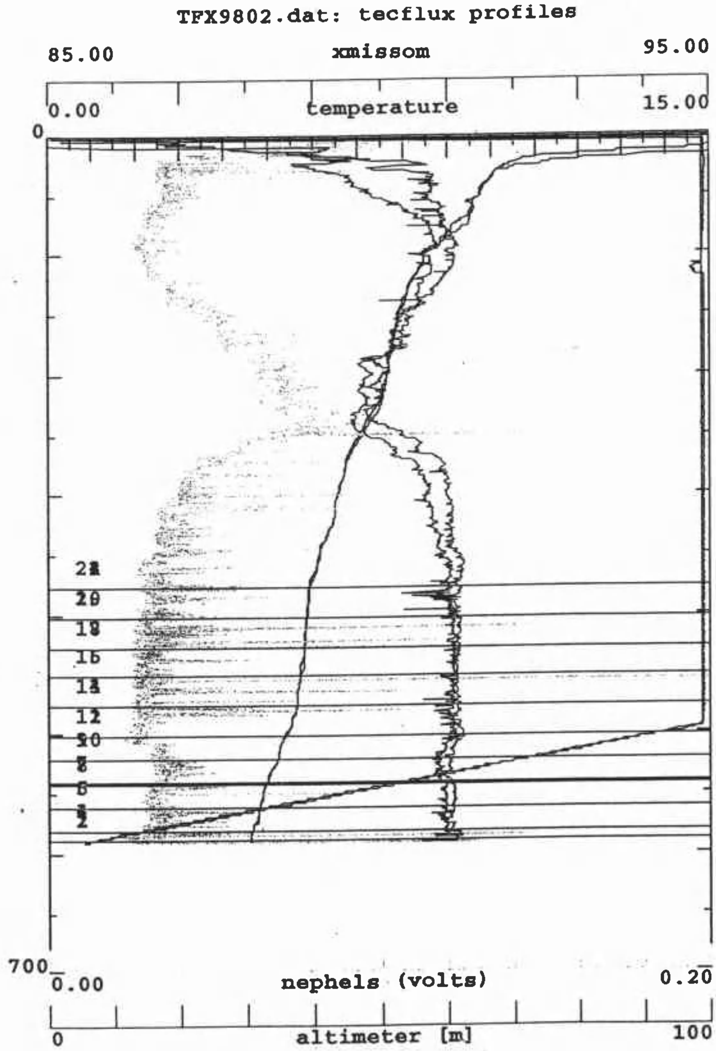
TFX9801.dat: tecflux profiles



```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\CTDdata\TFX9802.dat
* Software Version 5.0
* Temperature SN = 32111
* Conductivity SN = 394
* Number of Bytes Per Scan = 30
* Number of Voltage Words = 4
* System UpLoad Time = Aug 20 1998 05:49:46
* Ship:
* Cruise:
* Station:    TFX98.02.CTD2
* Latitude:   44 40.10
* Longitude:  125 05.82
# interval = seconds: 0.0416667
# start_time = Aug 20 1998 05:49:46
# sensor 0 = Frequency  0  temperature, primary, 32111, 09-Jul-1998
# sensor 1 = Frequency  1  conductivity, primary, 394, 09-Jul-1998, cpcor = -
9.5700e-08
# sensor 2 = Frequency  2  pressure, 22003, 22-Jul-1997
# sensor 3 = Frequency  3  temperature, secondary, 646, 09-Jul-1998
# sensor 4 = Frequency  4  conductivity, secondary, cpcor = -9.5700e-08
# sensor 5 = Extrnl Volt  1  nephelometer (IFREMER), measured voltage
# sensor 6 = Extrnl Volt  3  userpoly 0
# sensor 7 = Extrnl Volt  5  altimeter
# sensor 8 = Extrnl Volt  7  transmissometer, 1001d, factory
# datcnv_date = Aug 20 1998 06:33:14, 4.233
# datcnv_in = TFX9802.DAT TFX9802.CON
# rossum_date = Aug 20 1998 10:34:57, 4.233
# rossum_in = TFX9802.ROS TFX9802.CON
```

Bottle Position	Date Time	DepS	T068	Sal	Sigma-é00	Potemp068	
1	Aug 20 1998	589.198	4.6125	34.1976	27.0878	4.5667	(avg)
	06:06:34	0.046	0.0002	0.0004	0.0003	0.0002	(sdev)
3	Aug 20 1998	580.788	4.6639	34.1885	27.0748	4.6187	(avg)
	06:08:04	0.064	0.0001	0.00022	0.0002	0.0002	(sdev
5	Aug 20 1998	560.872	4.8085	34.1722	27.0457	4.7642	(avg)
	06:09:20	0.053	0.0009	0.0003	0.0003	0.0009	(sdev)
7	Aug 20 1998	541.539	4.9834	34.1462	27.0053	4.9401	(avg)
	06:10:45	0.182	0.0008	0.0002	0.0002	0.0008	(sdev)
9	Aug 20 1998	521.354	5.2247	34.1083	26.9474	5.1821	(avg)
	06:12:34	0.074	0.0011	0.0003	0.0004	0.0011	(sdev)
11	Aug 20 1998	501.159	5.4218	34.0818	26.9031	5.3802	(avg)
	06:14:05	0.137	0.0012	0.0004	0.0005	0.0012	(sdev)
13	Aug 20 1998	476.660	5.6452	34.0765	26.8719	5.6049	(avg)
	06:15:47	0.064	0.0005	0.0003	0.0003	0.0005	(sdev)
15	Aug 20 1998	451.384	5.7083	34.0729	26.8612	5.6700	(avg)
	06:17:23	0.124	0.0005	0.0002	0.0002	0.0005	(sdev)
17	Aug 20 1998	426.730	5.8046	34.0675	26.8448	5.7682	(avg)
	06:19:12	0.090	0.0016	0.0005	0.0006	0.0016	(sdev)
19	Aug 20 1998	402.027	5.8579	34.0640	26.8353	5.8234	(avg)
	06:21:05	0.075	0.0008	0.0003	0.0003	0.0008	(sdev)
21	Aug 20 1998	377.285	5.9227	34.0534	26.8186	5.8902	(avg)
	06:22:44	0.058	0.0006	0.0003	0.0002	0.0006	(sdev)

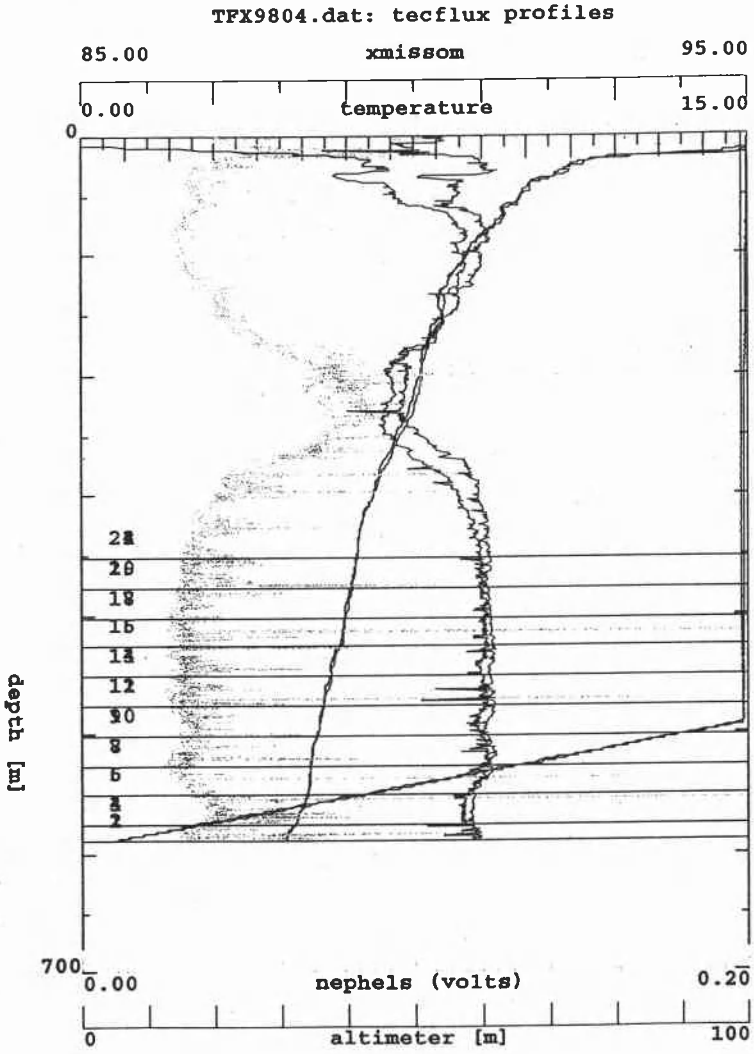
TFX9802.dat: tecflux profiles



```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\CTDdata\TFX9804.dat
* Software Version 5.0
* Temperature SN = 32111
* Conductivity SN = 394
* Number of Bytes Per Scan = 30
* Number of Voltage Words = 4
* System UpLoad Time = Aug 20 1998 17:46:23
* Ship:       R/V Brown
* Cruise:     TFX98
* Station:    TFX98.04.CTD3
* Latitude:   44 40.15
* Longitude:  125 05.95
# interval = seconds: 0.0416667
# start_time = Aug 20 1998 17:46:23
# sensor 0 = Frequency  0  temperature, primary, 32111, 09-Jul-1998
# sensor 1 = Frequency  1  conductivity, primary, 394, 09-Jul-1998, cpcor = -9.5700e-0
# sensor 2 = Frequency  2  pressure, 22003, 22-Jul-1997
# sensor 3 = Frequency  3  temperature, secondary, 646, 09-Jul-1998
# sensor 4 = Frequency  4  conductivity, secondary, cpcor = -9.5700e-08
# sensor 5 = Extrnl Volt  1  nephelometer (IFREMER), measured voltage
# sensor 6 = Extrnl Volt  3  userpoly 0
# sensor 7 = Extrnl Volt  5  altimeter
# sensor 8 = Extrnl Volt  7  transmissometer, 1001d, factory
# datcnv_date = Aug 21 1998 04:11:06, 4.233
# datcnv_in = TFX9804.DAT TFX9804.CON
# rossum_date = Aug 21 1998 04:35:58, 4.233
# rossum_in = TFX9804.ROS TFX9804.CON
```

Bottle Position	Date Time	DepS	T068	Sal	Sigma-é00	Potemp068
1	Aug 20 1998	588.326	4.6422	34.1985	27.0852	4.5964 (avg)
	18:02:39	0.082	0.0005	0.0003	0.0002	0.0005 (sdev)
3	Aug 20 1998	575.133	4.8474	34.1704	27.0402	4.8018 (avg)
	18:04:28	0.081	0.0012	0.0004	0.0003	0.0012 (sdev)
5	Aug 20 1998	550.511	5.1056	34.1288	26.9777	5.0610 (avg)
	18:06:20	0.041	0.0008	0.0003	0.0003	0.0008 (sdev)
7	Aug 20 1998	525.775	5.1874	34.1040	26.9484	5.1445 (avg)
	18:07:49	0.069	0.0002	0.0003	0.0002	0.0002 (sdev)
9	Aug 20 1998	500.752	5.3272	34.0906	26.9212	5.2859 (avg)
	18:09:37	0.051	0.0002	0.0002	0.0002	0.0002 (sdev)
11	Aug 20 1998	475.981	5.4639	34.0772	26.8942	5.4243 (avg)
	18:11:33	0.036	0.0003	0.0003	0.0002	0.0003 (sdev)
13	Aug 20 1998	451.297	5.6429	34.0692	26.8661	5.6049 (avg)
	18:13:04	0.068	0.0002	0.0003	0.0003	0.0002 (sdev)
15	Aug 20 1998	426.222	5.8237	34.0618	26.8380	5.7872 (avg)
	18:14:43	0.046	0.0007	0.0003	0.0002	0.0007 (sdev)
17	Aug 20 1998	401.436	5.9464	34.0602	26.8213	5.9118 (avg)
	18:16:28	0.111	0.0004	0.0002	0.0002	0.0004 (sdev)
19	Aug 20 1998	376.449	6.1053	34.0482	26.7916	6.0724 (avg)
	18:18:11	0.117	0.0002	0.0002	0.0002	0.0002 (sdev)
21	Aug 20 1998	351.839	6.2271	34.0429	26.7716	6.1961 (avg)
	18:19:59	0.073	0.0005	0.0003	0.0002	0.0005 (sdev)

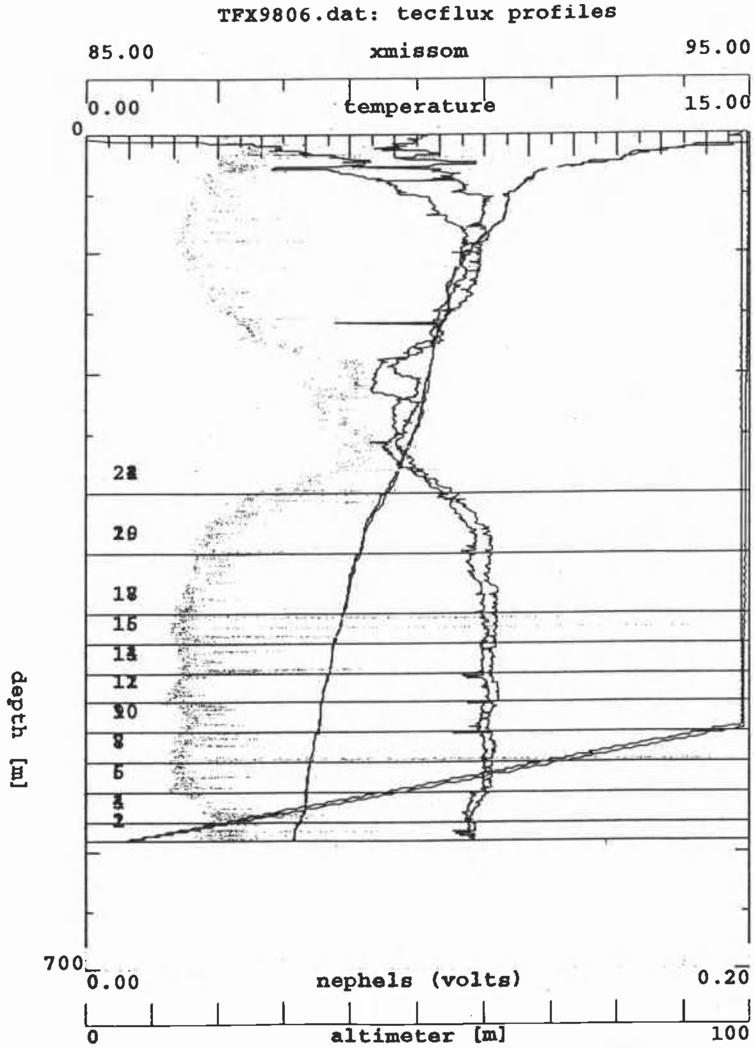
TFX9804.dat: tecflux profiles



```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\CTDdata\TFX9806.dat
* Software Version 5.0
* Temperature SN = 32111
* Conductivity SN = 394
* Number of Bytes Per Scan = 30
* Number of Voltage Words = 4
* System UpLoad Time = Aug 21 1998 01:16:31
* Ship:       R/V Brown
* Cruise:     TFX98
* Station:    TFX98.06.CTD4
* Latitude:   44 40.20
* Longitude:  125 05.83
# interval = seconds: 0.0416667
# start_time = Aug 21 1998 01:16:31
# sensor 0 = Frequency  0  temperature, primary, 32111, 09-Jul-1998
# sensor 1 = Frequency  1  conductivity, primary, 394, 09-Jul-1998, cpcor = -9.5700e-
# sensor 2 = Frequency  2  pressure, 22003, 22-Jul-1997
# sensor 3 = Frequency  3  temperature, secondary, 646, 09-Jul-1998
# sensor 4 = Frequency  4  conductivity, secondary, cpcor = -9.5700e-08
# sensor 5 = Extrnl Volt  1  nephelometer (IFREMER), measured voltage
# sensor 6 = Extrnl Volt  3  userpoly 0
# sensor 7 = Extrnl Volt  5  altimeter
# sensor 8 = Extrnl Volt  7  transmissometer, 1001d, factory
# datcnv_date = Aug 21 1998 04:15:22, 4.233
# datcnv_in = TFX9806.DAT TFX9806.CON
# rossum_date = Aug 21 1998 04:45:01, 4.233
# rossum_in = TFX9806.ROS TFX9806.CON
```

Bottle Position	Date Time	DepS	T068	Sal	Sigma-é00	Potemp068
1	Aug 21 1998	590.522	4.7672	34.1815	27.0580	4.7206 (avg)
	01:32:20	0.182	0.0116	0.0025	0.0032	0.0116 (sdev)
3	Aug 21 1998	575.326	4.9263	34.1583	27.0217	4.8803 (avg)
	01:33:28	0.062	0.0002	0.0002	0.0002	0.0002 (sdev)
5	Aug 21 1998	550.078	5.0292	34.1265	26.9846	4.9849 (avg)
	01:34:46	0.048	0.0003	0.0002	0.0002	0.0003 (sdev)
7	Aug 21 1998	524.666	5.1660	34.1093	26.9551	5.1233 (avg)
	01:36:07	0.169	0.0005	0.00044	0.0003	0.0005 (sdev
9	Aug 21 1998	500.303	5.3240	34.0910	26.9219	5.2828 (avg)
	01:37:09	0.076	0.0012	0.0004	0.0004	0.0012 (sdev)
11	Aug 21 1998	474.868	5.3952	34.0851	26.9086	5.3560 (avg)
	01:38:15	0.098	0.0023	0.0020	0.0018	0.0023 (sdev)
13	Aug 21 1998	450.008	5.5705	34.0682	26.8741	5.5328 (avg)
	01:39:15	0.053	0.0007	0.0002	0.0002	0.0007 (sdev)
15	Aug 21 1998	425.010	5.6632	34.0665	26.8613	5.6273 (avg)
	01:40:26	0.101	0.0025	0.0008	0.0007	0.0025 (sdev)
17	Aug 21 1998	399.935	5.8815	34.0611	26.8300	5.8472 (avg)
	01:41:43	0.052	0.0002	0.0002	0.0002	0.0002 (sdev)
19	Aug 21 1998	349.704	6.2570	34.0285	26.7564	6.2261 (avg)
	01:43:19	0.137	0.0005	0.0003	0.0002	0.0005 (sdev)
21	Aug 21 1998	300.143	6.8157	34.0095	26.6675	6.7880 (avg)
	01:44:59	0.034	0.0016	0.0004	0.0004	0.0016 (sdev)

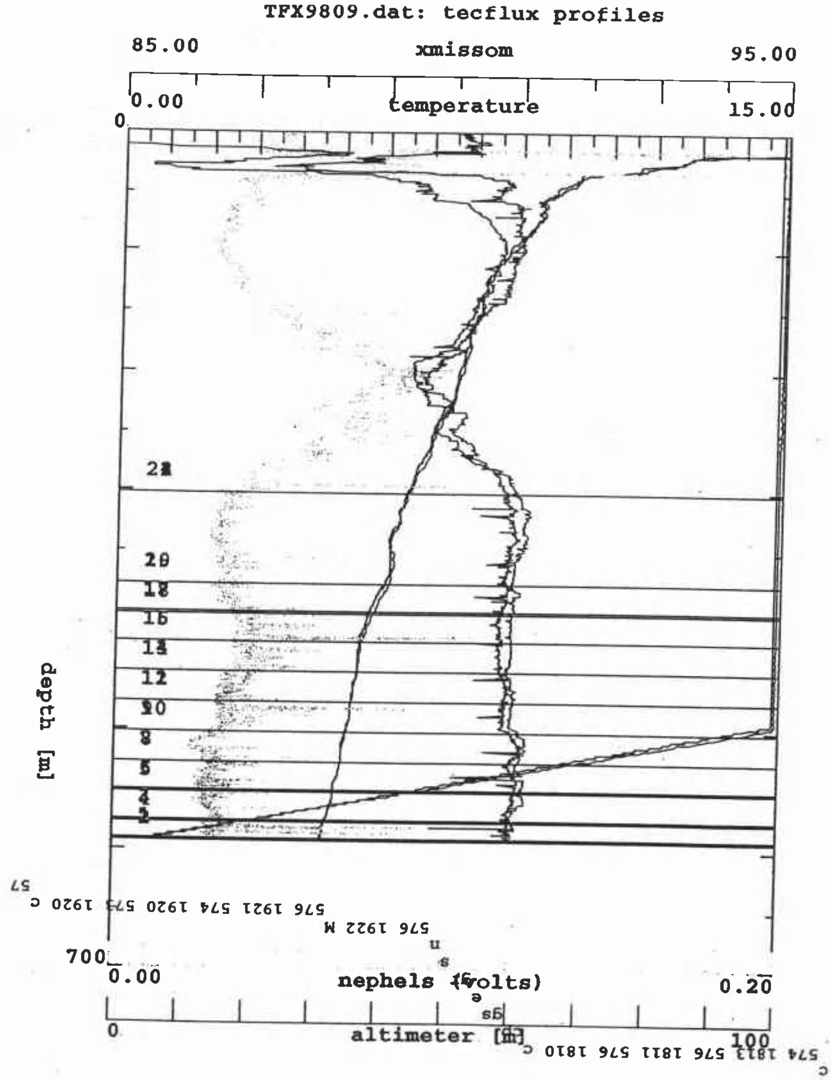
TFX9806.dat: tecflux profiles



```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\CTDdata\TFX9809.dat
* Software Version 5.0
* Temperature SN = 32111
* Conductivity SN = 394
* Number of Bytes Per Scan = 30
* Number of Voltage Words = 4
* System UpLoad Time = Aug 21 1998 18:11:06
* Ship:        R/V Brown
* Cruise:      TFX98
* Station:     TFX98.09.CTD5
* Latitude:    44 40.185
* Longitude:  125 05.885
# interval = seconds: 0.0416667
# start_time = Aug 21 1998 18:11:06
# sensor 0 = Frequency  0  temperature, primary, 32111, 09-Jul-1998
# sensor 1 = Frequency  1  conductivity, primary, 394. 09-Jul-1998, cpcor = -9.5700e-0
# sensor 2 = Frequency  2  pressure, 22003, 22-Jul-1997
# sensor 3 = Frequency  3  temperature, secondary, 646, 09-Jul-1998
# sensor 4 = Frequency  4  conductivity, secondary, cpcor = -9.5700e-08
# sensor 5 = Extrnl Volt  1  nephelometer (IFREMER), measured voltage
# sensor 6 = Extrnl Volt  3  userpoly 0
# sensor 7 = Extrnl Volt  5  altimeter
# sensor 8 = Extrnl Volt  7  transmissometer, 1001d. factory
# datcnv_date = Aug 21 1998 22:01:33, 4.233
# datcnv_in = TFX9809.DAT TFX9809.CON
# rossum_date = Aug 21 1998 22:04:01, 4.233
# rossum_in = TFX9809.ROS TFX9809.CON
```

Bottle Position	Date Time	DepS	T068	Sal00	Sigma-é00	Potemp068	
1	Aug 21 1998	591.618	4.7092	34.1889	27.0703	4.6628	(avg)
	18:28:03	0.116	0.0043	0.0011	0.0013	0.0043	(sdev)
3	Aug 21 1998	575.808	4.8229	34.1651	27.0387	4.7774	(avg)
	18:30:06	0.041	0.0003	0.0003	0.0002	0.0003	(sdev)
5	Aug 21 1998	550.536	5.0054	34.1293	26.9895	4.9612	(avg)
	18:31:54	0.056	0.0011	0.0003	0.0003	0.0011	(sdev)
7	Aug 21 1998	526.131	5.1718	34.1115	26.9561	5.1290	(avg)
	18:33:35	0.165	0.0008	0.0004	0.0004	0.0008	(sdev)
9	Aug 21 1998	501.177	5.2786	34.0939	26.9295	5.2375	(avg)
	18:35:09	0.222	0.0010	0.0003	0.0003	0.0009	(sdev)
11	Aug 21 1998	476.612	5.3716	34.0853	26.9116	5.3322	(avg)
	18:36:50	0.131	0.0002	0.0002	0.0002	0.0002	(sdev)
13	Aug 21 1998	451.470	5.4964	34.0696	26.8841	5.4588	(avg)
	18:38:14	0.141	0.0004	0.0003	0.0003	0.0004	(sdev)
15	Aug 21 1998	426.228	5.5242	34.0666	26.8781	5.4888	(avg)
	18:39:47	0.101	0.0002	0.0002	0.0002	0.0002	(sdev)
17	Aug 21 1998	401.830	5.7351	34.0507	26.8398	5.7011	(avg)
	18:41:31	0.208	0.0008	0.0002	0.0002	0.0008	(sdev)
19	Aug 21 1998	377.215	6.1086	34.0497	26.7923	6.0756	(avg)
	18:42:57	0.080	0.0006	0.0002	0.0002	0.0006	(sdev)
21	Aug 21 1998	302.375	6.5291	33.9893	26.6896	6.5019	(avg)
	18:46:16	0.072	0.C007	0.0002	0.0002	0.0007	(sdev)

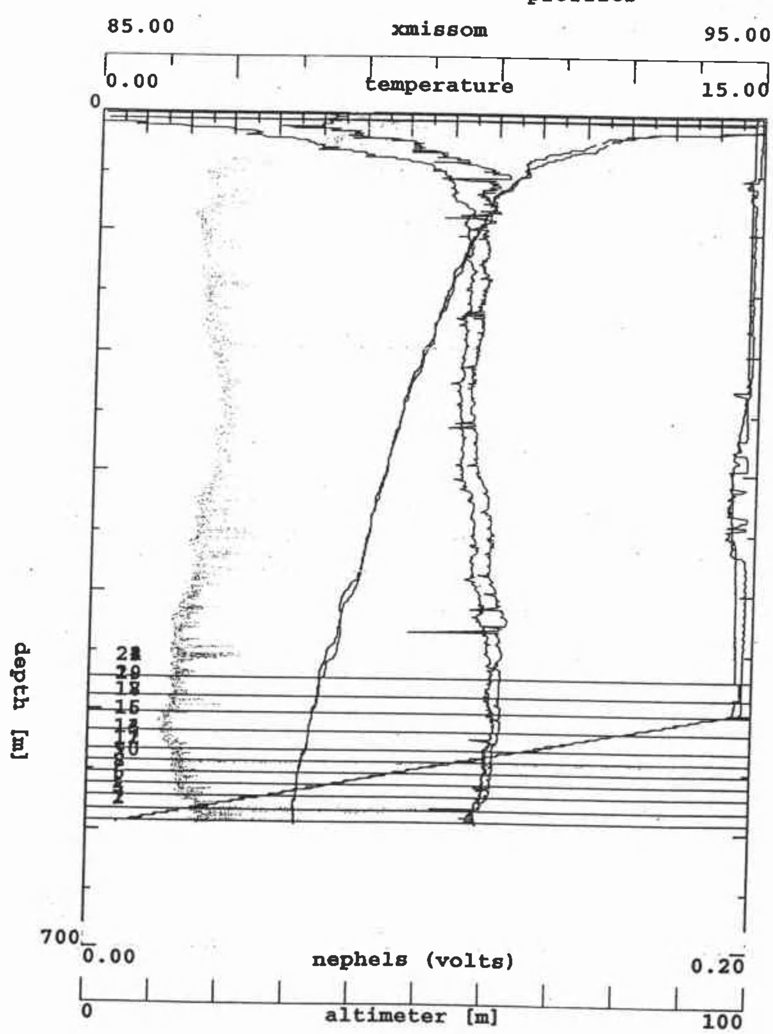
TFX9809.dat: tecflux profiles



```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\CTDdata\TFX9811.dat
* Software Version 5.0
* Temperature SN = 32111
* Conductivity SN = 394
* Number of Bytes Per Scan = 30
* Number of Voltage Words = 4
* System UpLoad Time = Aug 22 1998 22:52:16
* Ship:        R/V Brown
* Cruise:      TFX98
* Station:     TFX98.11.CTD6
* Latitude:    44 40.23
* Longitude:   125 05.88
# interval = seconds: 0.0416667
# start_time = Aug 22 1998 22:52:16
# sensor 0 = Frequency  0  temperature, primary, 32111, 09-Jul-1998
# sensor 1 = Frequency  1  conductivity, primary, 394, 09-Jul-1998, cpcor = -9.5700e-
# sensor 2 = Frequency  2  pressure, 22003, 22-Jul-1997
# sensor 3 = Frequency  3  temperature, secondary, 646, 09-Jul-1998
# sensor 4 = Frequency  4  conductivity, secondary, cpcor = -9.5700e-08
# sensor 5 = Extrnl Volt  1  nephelometer (IFREMER), measured voltage
# sensor 6 = Extrnl Volt  3  userpoly 0
# sensor 7 = Extrnl Volt  5  altimeter
# sensor 8 = Extrnl Volt  7  transmissometer, 1001d, factory
# datcnv_date = Aug 23 1998 01:38:13, 4.233
# datcnv_in = TFX9812.DAT TFX9812.CON
# rossum_date = Aug 23 1998 01:40:18, 4.233
# rossum_in = TFX9812.ROS TFX9812.CON
```

Bottle Position	Date Time	DepS	T068	Sal00	Sigma-é00	Potemp068	
1	Aug 22 1998	592.339	4.7118	34.1865	27.0681	4.6654	(avg)
	23:10:19	0.072	0.0003	0.0003	0.0002	0.0003	(sdev)
3	Aug 22 1998	581.596	4.7103	34.1867	27.0684	4.6648	(avg)
	23:11:41	0.176	0.0003	0.0002	0.0002	0.0003	(sdev)
5	Aug 22 1998	571.397	4.7519	34.1778	27.0566	4.7071	(avg)
	23:12:41	0.088	0.0025	0.0011	0.0011	0.0025	(sdev)
7	Aug 22 1998	561.570	4.7788	34.1730	27.0498	4.7346	(avg)
	23:13:57	0.095	0.0003	0.00022	0.0002	0.0003	(sdev
9	Aug 22 1998	551.530	4.8121	34.1650	27.0395	4.7686	(avg)
	23:14:57	0.082	0.0045	0.0014	0.0015	0.0044	(sdev)
11	Aug 22 1998	541.933	4.8740	34.1576	27.0267	4.8311	(avg)
	23:15:56	0.137	0.0005	0.0002	0.0002	0.0005	(sdev)
13	Aug 22 1998	532.308	4.9780	34.1432	27.0034	4.9354	(avg)
	23:16:57	0.089	0.0004	0.0003	0.0002	0.0004	(sdev)
15	Aug 22 1998	517.075	5.0248	34.1310	26.9883	4.9833	(avg)
	23:18:14	0.174	0.0009	0.0007	0.0007	0.0009	(sdev)
17	Aug 22 1998	501.944	5.0977	34.1190	26.9704	5.0572	(avg)
	23:19:25	0.181	0.0003	0.0002	0.0002	0.0003	(sdev)
19	Aug 22 1998	487.104	5.2177	34.0926	26.9354	5.1780	(avg)
	23:20:38	0.442	0.0025	0.0008	0.0009	0.0025	(sdev)
21	Aug 22 1998	472.048	5.3205	34.0800	26.9133	5.2817	(avg)
	23:22:15	0.087	0.0005	0.0002	0.0002	0.0005	(sdev)

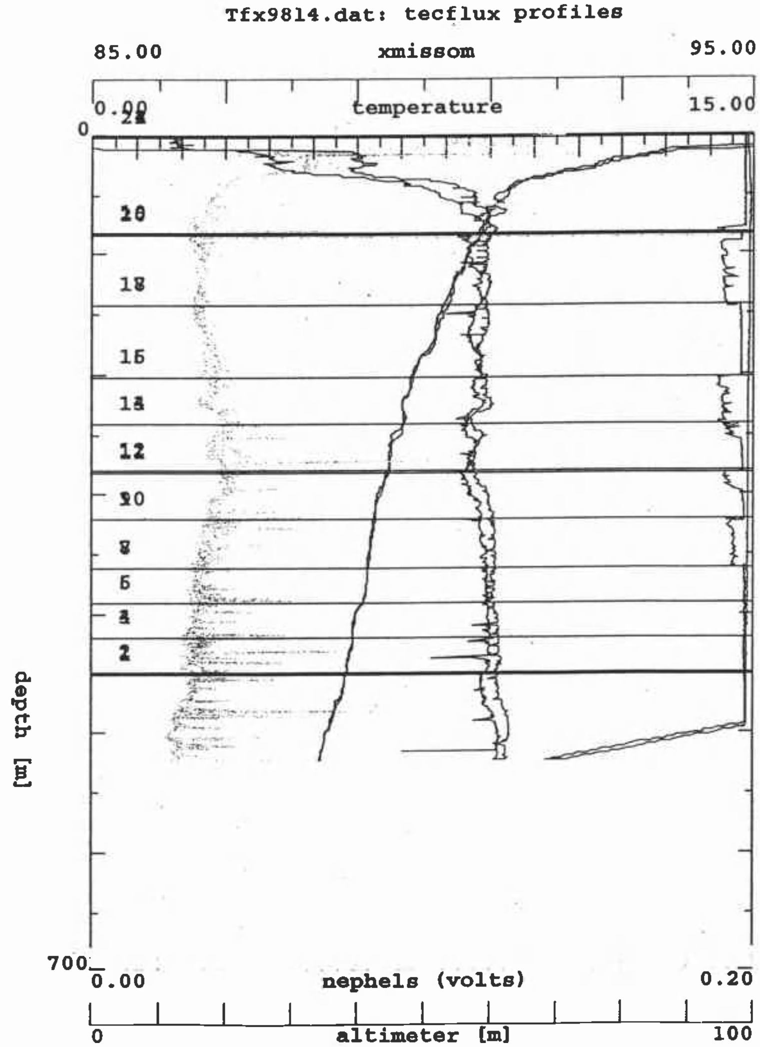
TFX9812.dat: tecflux profiles



```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\CTDdata\TFX9814.dat
* Software Version 5.0
* Temperature SN = 32111
* Conductivity SN = 394
* Number of Bytes Per Scan = 30
* Number of Voltage Words = 4
* System UpLoad Time = Aug 23 1998 13:46:20
* Ship:       R/V Brown
* Cruise:     TFX98
* Station:    TFX98.14.CTD7
* Latitude:   44 40.23
* Longitude:  125 05.885
* * note that the SCS data file is tagged as CTD 6 but CTD 6 was not recorded.
* * THis site is on top of the previous - just north of the bubble field ("meth" )
# interval = seconds: 0.0416667
# start_time = Aug 23 1998 13:46:20
# sensor 0 = Frequency  0  temperature, primary, 32111, 09-Jul-1998
# sensor 1 = Frequency  1  conductivity, primary, 394, 09-Jul-1998, cpcor = -9.5700e-
08
# sensor 2 = Frequency  2  pressure, 22003, 22-Jul-1997
# sensor 3 = Frequency  3  temperature, secondary, 646, 09-Jul-1998
# sensor 4 = Frequency  4  conductivity, secondary, cpcor = -9.5700e-08
# sensor 5 = Extrnl Volt  1  nephelometer (IFREMER), measured voltage
# sensor 6 = Extrnl Volt  3  userpoly 0
# sensor 7 = Extrnl Volt  5  altimeter
# sensor 8 = Extrnl Volt  7  transmissometer, 1001d, factory
# datcnv_date = Aug 23 1998 16:36:21, 4.233
# datcnv_in = TFX9814.DAT TFX9814.CON
# rossum_date = Aug 23 1998 17:29:38, 4.233
# rossum_in = TFX9814.ROS TFX9814.CON
```

Bottle Position	Date Time	DepS	T068	Sal00	Sigma-é00	Potemp068	
1	Aug 23 1998	450.325	5.8090	34.0647	26.8424	5.7704	(avg)
	14:02:38	0.118	0.0005	0.0002	0.0002	0.0006	(sdev)
3	Aug 23 1998	420.066	5.9221	34.0465	26.8136	5.8859	(avg)
	14:03:50	0.054	0.0002	0.0002	0.0002	0.0002	(sdev)
5	Aug 23 1998	391.331	6.1544	34.0483	26.7856	6.1200	(avg)
	14:05:12	0.094	0.0022	0.0004	0.0004	0.0022	(sdev)
7	Aug 23 1998	361.667	6.2718	34.0439	26.7668	6.2397	(avg)
	14:06:52	0.282	0.0039	0.0003	0.0007	0.0039	(sdev)
9	Aug 23 1998	321.988	6.4280	34.0341	26.7384	6.3992	(avg)
	14:08:21	0.229	0.0002	0.0003	0.0003	0.0002	(sdev)
11	Aug 23 1998	281.180	6.7564	34.0264	26.6886	6.7306	(avg)
	14:09:57	0.094	0.0004	0.0002	0.0002	0.0004	(sdev)
13	Aug 23 1998	242.226	7.0475	34.0036	26.6307	7.0249	(avg)
	14:11:49	0.071	0.0031	0.0004	0.0004	0.0031	(sdev)
15	Aug 23 1998	203.005	7.2687	33.9693	26.5726	7.2494	(avg)
	14:14:01	0.185	0.0011	0.0003	0.0003	0.0011	(sdev)
17	Aug 23 1998	142.824	7.9737	33.8588	26.3838	7.9594	(avg)
	14:16:20	0.084	0.0018	0.0007	0.0006	0.0018	(sdev)
19	Aug 23 1998	83.495	8.7814	33.4614	25.9493	8.7726	(avg)
	14:18:27	0.083	0.0006	0.0004	0.0004	0.0006	(sdev)
21	Aug 23 1998	2.461	16.3881	31.2506	22.7797	16.3877	(avg)
	14:22:05	0.094	0.0048	0.0005	0.0014	0.0048	(sdev)

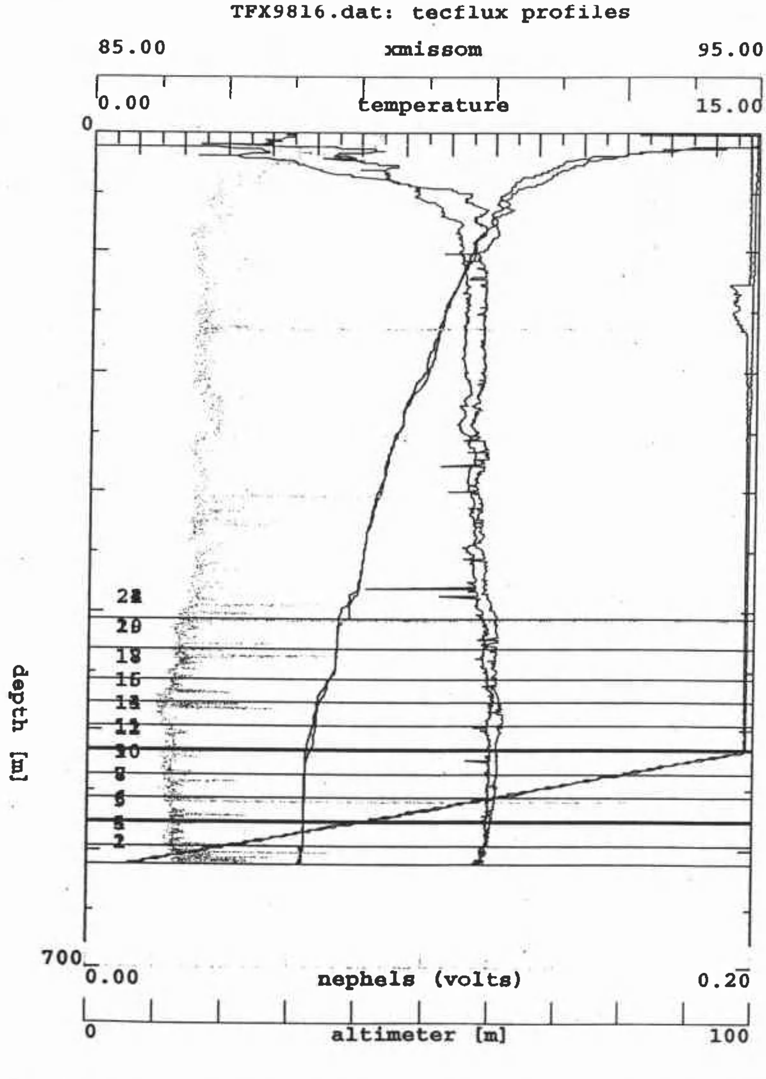
Tfx9814.dat: tecflux profiles



```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\CTDdata\TFX9816.dat
* Software Version 5.0
* Temperature SN = 32111
* Conductivity SN = 394
* Number of Bytes Per Scan = 30
* Number of Voltage Words = 4
* System UpLoad Time = Aug 23 1998 22:12:23
* Ship:        R/V Brown
* Cruise:      TFX98
* Station:     TFX98.16.CTD8
* Latitude:    44 40.38
* Longitude:   125 05.89
# interval = seconds: 0.0416667
# start_time = Aug 23 1998 22:12:23
# sensor 0 = Frequency  0  temperature, primary, 32111, 09-Jul-1998
# sensor 1 = Frequency  1  conductivity, primary, 394, 09-Jul-1998, cpcor = -9.5700e-08
# sensor 2 = Frequency  2  pressure, 22003, 22-Jul-1997
# sensor 3 = Frequency  3  temperature, secondary, 646, 09-Jul-1998
# sensor 4 = Frequency  4  conductivity, secondary, cpcor = -9.5700e-08
# sensor 5 = Extrnl Volt  1  nephelometer (IFREMER), measured voltage
# sensor 6 = Extrnl Volt  3  userpoly 0
# sensor 7 = Extrnl Volt  5  altimeter
# sensor 8 = Extrnl Volt  7  transmissometer, 1001d, factory
# datcnv_date = Aug 23 1998 22:55:54, 4.233
# datcnv_in = TFX9816.DAT TFX9816.CON
# rossum_date = Aug 23 1998 22:58:44, 4.233
# rossum_in = TFX9816.ROS TFX9816.CON
```

Bottle Position	Date Time	DepS	T068	Sal00	Sigma-é00	Potemp068
1	Aug 23 1998	611.327	4.7732	34.1755	27.0528	4.7249 (avg)
	22:30:28	0.051	0.0079	0.0028	0.0031	0.0078 (sdev)
3	Aug 23 1998	595.922	4.8689	34.1573	27.0275	4.8215 (avg)
	22:31:54	0.075	0.0003	0.0003	0.0002	0.0002 (sdev)
5	Aug 23 1998	576.150	4.8615	34.1580	27.0287	4.8157 (avg)
	22:33:16	0.223	0.0002	0.0002	0.0002	0.0002 (sdev)
7	Aug 23 1998	555.766	4.8742	34.1559	27.0254	4.8301 (avg)
	22:34:26	0.048	0.0009	0.00033	0.0003	0.0009 (sdev
9	Aug 23 1998	535.909	4.8852	34.1549	27.0232	4.8427 (avg)
	22:36:01	0.108	0.0020	0.0004	0.0004	0.0020 (sdev)
11	Aug 23 1998	516.374	4.9196	34.1506	27.0158	4.8786 (avg)
	22:37:24	0.183	0.0040	0.0011	0.0012	0.0040 (sdev)
13	Aug 23 1998	496.304	5.0750	34.1245	26.9772	5.0351 (avg)
	22:38:30	0.049	0.0013	0.0006	0.0006	0.0013 (sdev)
15	Aug 23 1998	476.291	5.1675	34.1043	26.9504	5.1290 (avg)
	22:39:32	0.109	0.0002	0.0003	0.0002	0.0002 (sdev)
17	Aug 23 1998	456.521	5.4074	34.0780	26.9014	5.3697 (avg)
	22:40:40	0.073	0.0040	0.0012	0.0014	0.0040 (sdev)
19	Aug 23 1998	431.121	5.5871	34.0633	26.8680	5.5510 (avg)
	22:42:04	0.085	0.0002	0.0002	0.0002	0.0002 (sdev)
21	Aug 23 1998	406.274	5.8638	34.0525	26.8254	5.8290 (avg)
	22:43:35	0.151	0.0024	0.0009	0.0007	0.0024 (sdev)

TFX9816.dat: tecflux profiles



Appendix 3
Sample Listings for Hydrographic Stations

Appendix 3. Sample list for hydrographic stations

Ronald H. Brown TECFLUX98 Benthic Program August 18-24, 1998

STATION	LOCATION	DATE	TIME	DEPTH (meters)	INSTIT.	INVESTIGATOR	QUANTITY	ANALYSIS
TFX98.01.CTD.1	44° 42.10 N	18/08/98	04:56	854	GEOMAR	Rehder	11 x 400mL	CH_4
	125° 06.0 W				OSU	McManus	12 x 250mL	O_2
					OSU	Collier	6 x 250mL	Trace Elements
							2 x 250mL	Salts
					HSU	deAngelis	1 x250mL	CH_4 oxidation
TFX98.02.CTD.2	44° 40.1 N	18/08/98	05:49	599	GEOMAR	Rehder	11 x 400mL	CH_4
	125° 05.8 W				GEOMAR	Winkler	10 x 100mL	He
					OSU	McManus	11 x 250mL	O_2
							11 x 20mL	pH
							22 x 20mL	Total CO_2
					OSU	Collier	6 x 250mL	Trace Elements
							2 x 250mL	Salts
TFX98.04.CTD.3	44° 40.10 N	19/08/98	18:28	600	GEOMAR	Rehder	12 x 400mL	CH_4
	125° 05.9 W				OSU	McManus	15 x 250mL	O_2
					OSU	Torres	11 x 30mL	^{13}C
					OSU	Torres	10 x 30mL	^{18}O
					HSU	deAngelis	10 x 125mL	CH_4 oxidation
TFX98.06.CTD.4	44° 40.20 N	20/08/98	01:53	610	GEOMAR	Rehder	12 x 400mL	CH_4
	125° 05.83 W				OSU	McManus	15 x 250mL	O_2
					OSU	Torres	12 x 30mL	^{13}C
					OSU	Torres	12 x 30mL	^{18}O
					HSU	deAngelis	11 x 125mL	CH_4 oxidation

STATION	LOCATION	DATE	TIME	DEPTH (meters)	INSTIT.	INVESTIGATOR	QUANTITY	ANALYSIS
TFX98.09.CTD.5	44° 40.20 N	20/08/98	18:10	603	GEOMAR	Rehder	11 x 400mL	CH_4
	125° 05.89 W				OSU	McManus	14 x 250mL	O_2
					OSU	Torres	11 x 30mL	^{13}C
					OSU	Torres	11 x 30mL	^{18}O
					HSU	deAngelis	11 x 125mL	CH_4 oxidation
					OSU	Collier	11 x 250mL	Trace Elements
TFX98.12.CTD.6	44° 40.24 N	22/08/98	23:25	608	GEOMAR	Rehder	11 x 400mL	CH_4
	125° 05.86 W				GEOMAR	Winkler	11 x 100mL	He
					OSU	McManus	13 x 250mL	O_2
							11 x 30mL	Total CO_2
							11 x 20mL	pH
					OSU	Torres	11 x 30mL	^{18}O
					OSU	Torres	11 x 30mL	^{13}C
					HSU	deAngelis	11 x 125mL	CH_4 oxidation
					OSU	Collier	11 x 250mL	Trace Elements
TFX98.14.CTD.7	44° 40.19 N	23/08/98	14:00	606	GEOMAR	Rehder	13 x 400mL	CH_4
	125° 05.91 W				OSU	McManus	14 x 250mL	O_2
							11 x 20mL	pH
					OSU	Torres	11 x 30mL	^{13}C
					OSU	Torres	11 x 30mL	^{18}O
					OSU	Collier	08 x 150mL	Trace Elements
							07 x 150mL	Salinity
TFX98.16.CTD.8	44° 40.49 N	24/08/98	02:10	626	GEOMAR	Rehder	13 x 400mL	CH_4
	125° 05.49 W				GEOMAR	Winkler	03 x 100mL	He
					OSU	McManus	14 x 250mL	O_2
					OSU	Torres	11 x 30mL	^{13}C
					OSU	Torres	11 x 30mL	^{18}O
					OSU	McManus	11 x 20mL	pH
					HSU	deAngelis	31 x 125mL	CH_4 oxidation

Appendix 4
Detailed ROPOS Logs

Ropos Log Dive 454

TFX98.05.R454					
TIME (GMT)	44° 40.XXX	125° 05.XXX	Depth	Comments	
8/20/98 19:39				Ropos in the water	
19:53				manifold pumping	
19:56				going down	
20:07				manifold spling	
20:12			400	man. spling	
20:17			500	man. spling	
20:21	44*40	125*05	569	stop	
20:25				power to man off	
20:25				back on	
20:34				Ropos back in cage	
20:35				Coming up - oil leak on Ropos	
20:44				Lost telemetry	
20:45				Back on	
20:47				Picture grab - reflector	
20:59				Cameras off	
21:04				Surface	
21:05	*******	******	*****	On Deck-oil change	

TFX98.08.R455				
TIME (GMT)	**44° 40.XXX**	**125° 05.XXX**	**Depth**	**Comments**
8/21/98 9:36				ROPOS in water
9:37				all stop
9:37				going down
				bottles 6 & 7 got surface seawater in them
10:00				one of ropes securing barrel broke; all stop
10:03				other rope securing barrel worn through; holding onto bridle
10:05				manuvering to grab barrel and secure
10:07				grabbed another rope to secure barrel; starting down again
10:07				stop
10:11				ROPOS out of cage;continuing down
10:21				cage stopped at 570 m;ROPOS heading down
10:23				bottom sighted;camera color adjustment
10:28				heading west
10:33				setting down to reposition (regrip) barrel
10:39				skirt observed to be pulling away when barrel held by clamp
10:43				recommencing search westward
10:51				moving ship 150 meters to the wset
10:56				bacterial mats; image grabbed
11:01				archive 2, tape 2 in
11:04				Moving ship to place stern over site
11:05				Frame grabbed B1
11:07				Craft nav restarted
11:10				Frame Grabbed B2
11:11				Frame Grabbed B3
11:11				Frame grabbed B4
11:12				Frame grabbed B5 Anenomie, shells
11:14				Frame grabbed B6 distr. clam shells
11:14				Frame grabbed B7 distr. clam shells
11:17				cage is 60m N of ROV
11:18				Frame grabbed B8 clams sighted
11:18				Frame grabbed B9
11:19				Frame grabbed B10
11:21				Starting VHS highlight tape
11:29				Frame grabbed B12
11:30				Frame grabbed B13
11:30				Frame grabbed B14
11:31				frame grabbed B15
11:34				SDS failure no com from Methane probe
11:38				highlight video off
11:42				highlight video on
11:44				highlight video off
11:45				returning to cage
11:48				ready to move 50m West
11:49				repeated ground faults on ROV
11:49				nav indicated that it has been using local time
11:50				ROV sighted by cage camera
11:53				moving ship 50m West
12:01				ROV returned to floor
12:01				heading West
12:03				sun star and crab sighted
12:04				bacterial mat sighted
12:05				highlight video on
12:05				frame grabbed B16
12:06				excellent bacterial mat sighted
12:06				frame grabbed B17
12:07				Beta tape on

12:08				frame grabbed B18		
12:08				frame grabbed B19		
12:08				seeking reference location from cage with sonar		
12:10				frame grabbed B20		
12:10				ROV 50m West of Cage 44.40.174 125.05.867		
12:12				frame grabbed B21		
12:12				frame grabbed B22		
12:12				frame grabbed B23		
12:13				frame grabbed B24		
12:15				Beta video off		
12:17				Beta video on		
12:18				frame grabbed B25		
12:19				extensive clam fields with localized mats		
12:20				Beta video off, then on		
12:21				Beta video off		
12:22				Highlight video off		
12:28				Changing Archive tape 1		
12:32				Changed Archive tape 3		
12:33				Highlight and Beta Video on		
12:34				Frame grabbed B26		
12:34				Frame grabbed B27		
12:34				Frame grabbed B28		
12:34				Archive 6 changed		
12:35				Frame grabbed B29,B30		
12:35				Noted excellent vents		
12:35				Frame grabbed B31		
12:36				three bubble holes located		
12:40				setting Benthos Barrel		
12:41				frame grabbed B32,B33		
12:42				frame grabbed B34 pic of barrel over plume		
12:42				still photo taken S2		
12:45				intense bacterial mats field of dead clams		
12:46				Beta Cam off		
12:48				barrel skirt fell off		
12:53				gas discharge out of barrel seam, flow too great for niskin sple		
12:54				frame grab B35 leak of gas from top of barrel		
12:55				tape archive 2 changed		
12:55				tape 3 in		
12:55				attempting to aright barrel for placement		
13:04				frame grabbed B36		
13:04				Beta video on		
13:05				frame grabbed B37		
13:06				barrel placed		
13:07				frame grab B38 barrel bottom interface		
13:07				Beta video off		
13:10				frame grab B39		
13:19				barrel sampler engaged		
13:22				highlight video off (SVHS)		
13:23				frame grab B40		
13:25				highlight video off		
13:26				ROV 40m West of Cage -- ROV @ 44.40.171 125.05.856		
13:27				depth 584m		
13:34				frame grab 40 and 41		
13:34				frame grab42		
13:36				frame grab 43		
13:39				highlight video on		
13:40				highlight video off		
13:41				frame grab 44 and 45-algal mats		

13:41				highlight video on		
13:47				frame grab 46 and 47-algal mats		
13:48				Algal sample collected bottle 6 (orange algae)		
13:48				frame grab 48		
13:52				frame grab 49		
13:55				Algal sample collected-Bottle 5		
13:55				highlight video off		
13:55				frame grab 49		
14:02				Algal sample collected-bottle 4		
14:14				Algal sample collected-bottle 3		
14:23				little animals in bottle 3		
14:25				Algal sample collected-bottle 2		
14:25				change archive 6- tape 3		
14:27				frame grab 50-neck of clam?		
14:28				frame grab51		
14:33				Algal sample collected-bottle 1;dirrectly over bubbles		
14:40				frame grab 51-scenic of barrel, clams		
14:41				highlight video on		
14:41				frame grab 52		
14:42				frame grab 53		
14:56				highlight video off		
15:02				changing tape (to 4) on Arca 2		
15:04				filled large sample chamber with water and bacterial		
15:10				grabed a clam		
15:11				frame grab 54		
15:11				frame grab 55		
15:25				frame grab 56, looking west carbonate blocks plus clams		
15:26				frame grab 57, looking west carbonate blocks plus clams		
15:27				three still photos looking east		
15:27				frame grab 58, looking east		
15:28				frame grab 59, looking south		
15:28				frame grab 56, looking south		
15:29				logging position		
	44° 40.1847	125° 05.8848		methane seepsite position		
15:49				grab the barrel		
15:53				ROPOS leaves the bottom following		
15:53				still having bubbles, 578 m		
15:55				still having bubbles, 564 m		
15:56				still having bubbles, 546 m		
15:58				still having bubbles, 537 m		
15:59				still having bubbles, 526 m		
16:00				no bubbles anymore, 525 m		
16:29				ROPOS back in garage		
16:30				Arca 3 video (tape 4) stoped		
16:38				ROPOS hits the surface, all videos off		

TFX98.11.R456				
TIME (GMT)	44° 40.XXX	125° 05.XXX	Depth	Comments
	44° 40.1847	125° 05.8848		seep site
8/22/98 1:42	1596	9060	a	ropos in, 1 SIO meter escaped, archive tapes 1,2,4,6 on
2:43			541	ROPOS out of cage
2:46	1796	8455		elevator spotted, everything still there
2:52				5 grabs of elevator
3:12	1841	8869	590	elevator location
3:37				current is .5(N)
3:41				found flow meter that fell off
3:49				SQUID
3:50				tapes changed
3:55				589 onthe bottom
3:57	2029	9025		
4:04				grab 9
4:06				still of elevater
4:07				teapot out ele.
4:09				grab9,still
4:10				grab10,11
4:11	2027	8691	592	grab11-15;still clam patch approx 4 m wide
				with scattered clams up to 10 m away. Several live clams
4:16				yellow line to elevator in view
4:18			591	grab 16; temporarily place beacon; pick up flow meter
4:31				elevator line caught in thrusters; coming back up;
				shutting down video; returning to cage
4:39				ropos in cage; going up
5:58				ropos repaired, back in the water
* note				substation site 1 is called clam 1 by Ropos team
7:05			592	SIO flowmeter "F" sited among clams
				Tapes, highlight tapes on during deployment
				grabs 1-29 of the area, installation of flowmeter
7:06	2031	8668	592	site 1 location
7:14				SVHS highlites tape off
7:21				grap 30 and 31 of elevator
7:16				grab 32 and still photo of elevator
7:23				grabs 33-36 of reach for flow meter
7:24				grab 37-39 of grasp
7:26				flow meter E in hand (not gas sampler)
7:30				change archive tape 1
7:31				view of meter F in operation
7:37				Deposit meter E near F while umbilical corrd is cleared
				About here highlite tapes were restarted
7:38				Change tapes, archives 2,3, and 6
7:40				grab 41 of bottom, still photo also
7:41				grab 42, F deployed and E on arm
7:42				Try deployment of E, still photo
7:44				E is now deploued, work on arrangement
7:47				grab 43 of E being set
7:48				grab 44, still photo of E
7:49				Stop 2 highlite tapes
7:54				back at cage
8:00				searching for a lelevator
8:03				large crab
8:06				spot elevator
8:14				Seep meter G in grasp
8:20				sponge in view, sandstorm swirling
8:22				storm clears and we are caught next to elevator anchor
8:28				still making sure that tether is not fouled with elevator

8:32				highlite video back on
8:35				grab 46, still photo of meters E and F deployed
8:37				grab 47,48, still photo of algal mat for deployment of G
8:39				grab 49,50 as closeups of mat and clams
8:40				grab 51 of clams and large snail
8:42				grabs 52,53 of close up clams with purple mantles
8:43				grab 54 of clams
8:45				grab 55 panorama of mat and clams
8:47				grab 56 of meter G going down
8:48				still photo of meter G going in
8:48				grabs57 and 58 of site
8:49				grab 59, still photo of G being set
8:51				grab 60 of meter on bottom
8:54				still photo of scene
8:55				still photo
8:57				still photo
9:00				Marie takes over
9:09				grab 63 of flowmeter
9:15				continuing to position flowmeters
9:16				grab 64 - close up of flowmeter
9:20				moving flowmeter E to new position
9:21				grab 65
9:21				grab 66 - moving flowmeter
9:25				grab 67 - flowmeter E
9:26				still photo; grab 67 - flowmeter E
9:29				still photo - flowmeter E position
9:30				grab 68 - flowmeter E position
9:32				grab 70; still photo of general area aroundflowmeter E
9:39				grab 71 - final placement of flowmeter E
9:40				beta tape on
9:41				still photos of flowmeter general area
9:41				grab 72 - overview of flowmeter area
9:42				still photo, grabs 73, 74 - overview of all 3 flowmeters
9:42				archive tapes 1, 2, 3, 6 (all)
9:44				moving off flowmeter site
9:46				picking up flasher
9:55				grab 75; still photo
9:56				still photo
9:57				grab 76 - bubbles (beautiful sight)
10:03				t-pod positioned at bubble site
10:03				grab 77
10:04				t-pod 2 meters, heading 307.2; depth 586 m
10:04				still photo
10:06				grab 78, still photo - t-pod, grab 79, 80
10:07				still photos
10:16				archive 4 stopped
10:37				back at elevator
10:43				highlight tape on
10:44				grab 81; gas sampler on elevator
10:45				gas sampler #1 taken from elevator
10:46				highlight tape off???
10:47				leaving elevator
10:50				arrived at bubbles
10:51				grab 82 - bubbles
10:52				grab 83; still photos
10:52				filling gas sampler #1
10:53				grabs 84 - 89 - gas sampler #1 and bubbles
10:56				grab 90; still photos - bubble hole

10:57				grab 91 - bubble hole
10:58				grabs 92, 93, photo stills - bubble hole close-up
10:59				grab 94, 95, 96 - weird critter morphs
11:00				Joe taking over log
11:00				grabs 97-104
11:03				attempting to sample white worm casings near vent
11:05				returning to elevator
11:05				no more Beta cam
11:08				highlight video off, monitor was down for archive 3&4
				but the tape was rolling
11:10				attempting to aright the beacon with pac-man arm
11:14				beacon successfuly arighted
11:16				headed NbyNE to elevator
11:18				located elevator
11:23				attempting to reattach sampler to rack
11:27				gas sampler 1 returned to cage mount
11:28				frame 105 grabbed
11:30				attempting to retrieve another gas sampler from cage
11:31				gas sampler #2 retrieved from cage
11:32				retunring to site of the gas vent
11:33				archive 3 changed from tape 4 to tape 5
11:34				found strobe
11:37				highlight video on
11:38				gas sampler 2 set over gas plume
11:39				fram grabed 106-108
11:42				sampler seated to bottom, attempting to flush
11:43				gas sampling completed, retutning to cage
11:48				Archives 2&3 changed
11:49				Archive 1 changed
11:53				Highlight video off
11:55				Attempting to seat gas sampler #2 onto cage mount
12:03				Gas sampler 3 knocked off, gas sampler 2 placed in its spot
12:04				Bungie placed and sampler sealed into cage mount 3
12:05				Highlight tape changed
12:07				setting up to retrieve barrel sampler which is tied down
12:10				rope snapped on line release, attempring to secure
12:11				line released into environment
12:13				slip knot holding barrels released, unthreading
12:15				heading to other side of cage to pull line through
12:24				pilot exchange
12:34				pulling line free from barrels will attempt to drape over
				cage to keep line away from thrusters
12:36				barrels freed from line, attempting to secure line
12:43				grabbed loose end of line, will try to secure to elevator cage.
12:45				draped line over top of elevator, moving to retrieve barrel
12:47				grabbed line handle on barrel
12:52				barrel out of cage
12:53				setting barrel down to get a better grip
12:54				checking gauges on ROV
12:55				grabbing ridgid handle on barrel
12:56				moving barrel to test position
12:58				ROV heading to cage
12:59				heading NNE 20m to clam site
13:01				frame grab 109
13:04				return to elevator
13:05				change archive 3- tape 6
13:06				head north-east to barrel
13:14				return to flow meters

13:16				change archive tape 2-tape 6
13:16				change archive 6-tape 6
13:16				change archive tape 1-tape 5
13:21				frame grab 110-zoom of live clams
13:21				Highlight video on
13:22				frame grab 111-zoom of live clams
13:22				frame grab 112-live clams
13:25				frame grab 113- clam bed
13:25				frame grab 114-barrel #1site
13:29				frame grab 115-barrel #1 site
13:31				frame grab 116-barrel site;live clams
13:33				deploy barrel #1 over live clams
13:33				frame grab 117- deployment of barrel #1
13:34				frame grab 118- barrel deployed
13:36				frame grab 119- skirt of barrel
13:37				frame grab 120- full barrel #1
13:38				Frame grab 121 and 122- clam site overview
13:43				frame grab 123-pull line on barrel
13:46				frame grab 124-pull line on barrel
13:54				barrel #1 engaged
13:54				frame grab 125-barrel #1 engaged
13:57				barrel bushed into sediment
14:00				barrel #1 repositioned
14:00				frame grab 126-repositioned barrel
14:01				bush barrel #1 down
14:05				push flaps down
14:05				frame grab 127-barrel skirt
14:07				frame grab 128- barrel overview
14:09				frame grab 129- barrel #1 overview
14:09				moving southwest-towards elevator
14:10				highlight video off
14:10				check gages
14:15				return to cage
14:25				return to flow meters (trying to find elevator)
14:32				return to elevator
14:35				retrieve dropped gas sampler #3
14:37				change archive 3-tape 7
14:43				frame grab 130-2gas vents
14:43				frame grab 131-small gas vents
14:44				frame grab 132, 133, 134
14:44				Vent 3 very active (most active #1 and #3)
14:45				frame grab 135, 136, 137- vent 3-deployment of gas spler
14:46				frame grab 138
14:48				frame grab 139- vent 3 with 10 cm scale
14:50				bacterial mat clogs gas sampler #3-no sample collected
14:52				soft ball on gas sampler 3 breaks
14:53				frame grab 140- vent 3
14:55				frame grab 141- vent 3-the gusher
14:55				frame grab 142- vent 3
14:56				frame grab 143- bubbles everywhere
15:04				back to elevator to put the gas sampler back
15:14				changing Arca 2-tape 7, Arca 6-tape 7 and Arca 1-tape 6
15:22				back at elevator
15:26				frame grab 144- put gas sple 3 back; disturb gas spler 2
15:33				rearranging gas sampler 2
15:46				fixed gas sampler 2 again
15:55				grab the first barrel to bring it back to the elevator
15:57				frame grame 145 - ROPOS grabbing the barrel

15:57				highlight video on
16:04				frame grab 146 - barrel back into elevator
16:09				highlight video off
16:16				barrel out of elevator
16:27				changing tape at Arca 3 to tape 8
16:33				frame grab 147- fauna pricture
16:34				frame grab 148- fauna pricture in detail
16:34				frame grab 149- fauna pricture; soft coral
16:39				frame grab 150- vent sites and bacterial mats
16:40				frame grab 151 - bacterial mats, detail
16:43				frame grab 152 - bacterial mats
16:45				frame grab 153 - bacterial mats, deploying barrel on them
16:47				frame grab 154 - deploying barrel next to a vent site
16:49				frame grab 155 - deploying barrel next to a vent site
16:49				frame grab 156 - deploying barrel next to a vent site
16:51				replacing the barrel
16:52				frame grab 157, new barrel site; still very close to vent
16:53				frame grab 158 - new barrel site
16:58				anne on watch
17:00				started trying to pull switch to turn on barrel
17:04				frame grab 159
17:?				saw oil leaking out of connector
17:16				twisted pin to trigger barrel; start repositioning barrel
17:24				barrel positioned; seal looks good; no frame grab
				because tape change needed at same time
17:28				archive tapes 2 and 6 changed
17:30				picked up beacon; it had been tipped over during deployment
				Sonar reflector hanging by a string. Beacon on a small rock
				but decided not to reposition it for fear of knocking off beac
17:31				start "slurping"; hose in the wrong direction
17:33				frame grab numbering starting over
17:41				released slurper from packman and took it in the other arm.
17:44				frame 1 (xxx162.001)
17:45				pumping into bottle 2
17:46				frame 2
17:47				frame 3
17:48				lost sample from slurper
17:48				touching the seafloor by slurper on a vent
				made vent more vigorous
17:49				adding more to bottle 2
17:51				slurping up yellow mats
17:52				slurper contact on seafloor started a small new vent
17:53:00				slurper filling bottles 3 and 4
17:56				slurping more yellow mats and sediment
17:58				sighted skirt from previous barrel dive
17:58				added material to bottle 4
17:58				added material to bottle 5
18:02:00				slightly bumped barrel during course of sampling; requested
				that sampling stay clear of barrel
18:03				added material to bottle 5
18:08				slurping
18:11				filling bottle 6
18:14				slurped beneath overhanging carbonate slab; frame 4
18:16				frame 5
18:16				frame 6; slurped dead sea urchin(?)
18:18				filled bottle 7; frame 7
18:19				changing archive tape drive 3 to tape 9
18:24				pick up benthic barrel; head toward elevator

18:32				sight elevator	
18:35				barrel placed in elevator	
18:38				retrieved radon sampler but dropped it when putting it	
				into the elevator	
18:40				retrieved radon sampler 3 sucessfully	
18:46				preparing to retrieve elevator	
19:11				ship moved 30 meters to make room for elevator to surface.	
19:19				Ropos releases elevator.	
19:20				Elavator in ascent. Should surface off port bow of Brown.	
19:23				Brown moves another10 meters east, to stay clear of elevat	
19:27				Archives 2 and 6 changed to tape 9; tape 8 finished.	
19:31				archive 1: tape 7 taken out and tape 8 put in.	
19:33				elevator on surface. Sighted by Brown 20 meters off port sid	
				Recovery operation commences.	
20:00				Elevator recovered, but both barrels fell out when	
				RIB tried to get the elevator on board.	
20:14				archive 3: tape 9 removed	
20:19	44.44.1623	125.80.8	591	Bubbles sighted. Rough carbonate and algal matsighted.	
20:19				Grab 8 and still photo taken of above mentioned site.	
20:27				Grab 9 of beds of clams	
20:30	?	8199			
20:31	1708	8077		Rough topography and low density of clams. Algal mats also	
				sighted. Archive 3, tape 10 started (gap from previous tape	
20:38	1699	7423			
20:39				scattered carbonate boulders. Very low density clams.	
20:45	1947	8052		Moderately intense clams	
20:48				grab 10	
20:50	2047	8343			
20:52	2146	8435		relatively smooth carbonate pavement and few	
				clams. Localized clam fields 2 to 3 meters wide.	
21:00	1839	7473			
21:02	1995	7594		Video clock turned on; it had been off	
21:06	2160	8112		barrel sighted. grab 11	
21:07				grab 12 of barrel	
21:19	2268	8050	597	fix on barrel	
21:25				ARCHIVE 9: remove tape 9, insert tape 10	
21:28				archive 1: remove tape 8, insert tape 9	
21:47				lift off bottom with barrel	
21:52			540	Ropos docks with cage	
22:01			300	Coming up	
22:12			0	surface EOD	
22:29				archive 3, tape 10 complete	
22:32				stopped archive 2, tape 10; archive 6,tape 10;	
22:35				stopped archive 1, tape 9	

TFX98.13.R457				
TIME (GMT)	44° 40.XXX	125° 05.XXX	Depth	Comments
8/23/98 1:23	223	784		Ropos in water
1:26				Archive 2 and 6 tape 1 start
1:32				Archive 1 tape 1 start
1:34				Archive 3 tape 1 starts
1:54				on bottom, near site
2:02	2033	8040	592	scattered boulders very low density of shells
2:07	2294	7567		start of west-bound transect, smal rocky debris, some larger
				boulders, widely scattered clams
2:13	2345	7777	597	lots of carbonate rubble no signs of anything active
2:18	2241	8533	594	lots of carbonate rubble no signs of anything active
2:21	2425	8118		small patch of clams 1-2 meters across
2:27	2453	7618		carbonates, no clams
2:37	2348	7858		carbonate rubble, no clams
2:44	2219	8038		under the cage
2:56	2440	7809	595	"trombone" gas sampler found
3:09				archive 1, tape 2 starts
3:11				archive 2 & 6 tape 2 begin
3:14			596	passing over ridge of carbonate
3:31				archive 3 tape 2 starts
4:05	2481	8686		back surveying, turn point
4:13	2386	7791		hole in the ground, gas sampler seen near it
4:27				small dense clam patch
4:28	2475	7992	598	grab3, "shrimp from hell" , grab 4
4:29				egg fish grab 5-7
4:30				grab 8 of patch
4:53				3 grabs of "surface dwellers suck"
5:12				change tape on archive #1, start of tape #3
5:15				change tape on archive #2 and 6, start of tape #3
5:18				change tape on archive #3, start of tape #3
5:38			602	same old same old: sea snow, rocks, mud, sea pens,
				mushroom corals, starfish, red fish
5:40				start tape 4 for archive 4
5:54			599	clam #4, grab 1
6:00				black stones, grabs 2, 3, 4
6:11				grab #5, white shelf-like layer
6:20				grab #6, gas sampler grabbed literally by Ropos
7:00				changing of the guard as pilot
7:02				Doug takes over
7:05				rocky bottom, large rocks
7:07				pallet jack in sight
7:14				clam cemetary
7:38				layered sheets
7:43				gnarly carbonates, holes and irregular
7:45				grabs 7, 8 of large hole in crust
7:46				mats of spider web like stuff, grabs 9-11
7:48				lose surface control, start up
7:50				Stop all archive tapes
7:53				Recover signals, restart tapes, start descent to bottom
8:05				problem on disk with grabs. save frame and seems OK
8:07				more sediment and few rocks exposed
8:10				start another transect in grid, heading west
8:11				flounder
8:15				metal plate?, possible rudder, larger rocks now
8:20				few more gnarly gocks
8:30				large orange jelly fish
8:41				bottom still in sight, small rocks NS MUS
8:43				starfish, crab, clamshells, all nead? grab s 14-16

8:45				mats and pink mushroom things, grab 17
8:49				small cobbles, approaching clam 2
8:54				bacterail mats
8:55				clam 1 in sight
9:13				archive 1 missing 9 minutes; archive 5 out - 4 in
9:17				grab 20; more clams
9:18	.1930	.7948		grab 21; former grab hole? (tv grab); grab 22,23
9:24				grab 24
9:28				tape 4 on archive 3 finished; tape 5 in
9:43	.1865	.8364		grab 25; clam 5
10:02				clam 6 (small field)
10:02				grab 26, 27
10:05				grab 28 - algal mat
10:12				clam 7; grab 30
10:14				mats
10:18				large clam field (clam 8)
10:24				grab 34
10:37				grab 35; beginning of the great clam hunt at clam 8
10:38				grab 36, 37
10:40				grab 39
10:41				grab 40
10:43				grab 41
11:00				log personel change
11:00				Attempting to sample clam specimens with the "pac-man" a
11:02				sample dig
11:03				image grab 42
11:04				sample transferred to box
11:07				setting position to sample floor fauna with "pac-man" again
11:08				sample taken
11:10				sample transferred to box
11:11				highlight video 5 changed for 6
11:13				image grab 43,44
11:15				archive 6 tape 6
11:16				headed to clam site 3
11:20				archive 1,2,&6 changed
11:24				reached clam 4, still seeking clam 3
11:25				reached clam field 3
11:25				image grab 45
11:26				highlight video on, same tape from last dive
11:27				image 46 taken, closeup of clam 3
11:27				image 47 grabbed
11:29				image 48 grabbed
11:30				new position for clam 3 called clam 3b .2356-.7998
11:32				image 49, 50 taken
11:33				image 51 -green piece of material, does not appear organic
11:37				sample taken, image 52 taken
11:42				sample transferred to box
11:45				another pac-man sample of clams taken from clam site 3
11:47				sample transferred to box
11:53				image taken 53, pac-man grab #3 from clam site 3b
11:57				pac-man sample taken, missed most of the target
12:01				pac-man sample taken
12:02				sample transferred to box
12:05				clam samples finished
12:07				clam site 3 depth 599m
12:12				seeking lost barrel
12:15				highlight video off
12:16				archive 6 was found not to be recording
12:30				bridge notified, ROPOS preparing to surface

TFX98.15.R458				
TIME (GMT)	**44° 40.XXX**	**125° 05.XXX**	**Depth**	**Comments**
8/23/98 15:46	2321	8123		Ropos in the water
8/23/98 15:47				starting all videos, ARCADE 1,2,3,6 all signed tape 1
8/23/98 15:57				rebooting ROPOS main software, all screens down
16:01				rebooting successful, all screens working
16:45			581	reaching final depth
16:45				ROPOS starts moving towrds north
16:52	2566	8088		Ropos position
17:07				anne on watch; frame 1 - rock that looks like half eaten loaf
				of bread; rearranging hold on flow meter so it doesn't
				obstruct view as much
17:29				frame 2 - big white starfish
17:39	2471	8052	600	frame 3 - arriving in region of scattered clams and algal mats
17:43				frame 4-8; 3 photos - overview of flowmeter site
17:46				frame 9-12 - closeup of clam bed next to flowmeter site
17:52				frame 13 - overview of flowmeter site
17:53	2466	8074	599	positioning flowmeter A; change archive 1,2,3,6 to tape 2
17:59				frame 15 - lowering flowmeter
18:12				heading to site for clam corral
18:59				pass over sign
19:18	2428	8020	599	arrive at site for clam corral; close to flowmeter A
19:21				frame 17, 18 of hole for clam corral
19:23	2423	7998	599	update location for clam corral
19:27				highlight tape on
19:31				grab 21 - installation of clam corral
19:46				frames 22-27 - clams successfully dumped into corral.
19:52				frames 28-30 - closeups of corral with clams; still photo too
19:53				archives 1,2,3,6 start tape 3. highlight tape off.
19:53				starting to find site for last flowmeter
20:00				watch flowmeter C freefall from cage
20:03	2305	8066	601	position of flowmeter on bottom. A long white line is trailing
				from the instrument and will be left behind. Can be used in 99
				as a reference for finding clam corral. distance and bearing
				of line to the clam corral are 36m and 016, respectively.
20:03				from bosun sign to clam corral, range and bearing are
				47.5m 186, respectively. Note: sign may drift. Take picture
				for reference in 99.
20:30				highlight video on for flowmeter C deployment
20:31				frame 33 - another shot of clam corral
20:36	2433	8054	600	flowmeter C installed next to clam corral. frame 34-35;
				2 still photos
20:41				approx 7 scenic still photos and frames 35-42 of flowmeter C
20:48				turn off highlights
20:51				head to meth site to try Hammond's flow meter idea
20:58				sight teapot. Flasher still going; teapot on its side
20:59				turned on highlight tape
21:01				frame 43 - overview of meth site
21:08				frame 44 - view of vent. vent flow rate appears much lower
				than during dive 456. New vent started. Clearly
				time-dependent
21:14				frame 47,48 Close up shot of a vent. looks like there is
				hydrate forming around it.
21:14				frame 49 as we back up. Also many still photos
21:15				All tapes shut down
21:25				ropos back in cage
22:03				ropos back on board

Appendix 5

Sample Distribution for Materials Collected During ROPOS Dives

ROPOS SAMPLES

TFX98.05.R454 no samples were taken

TFX98.08.R455	44°40.18 N, 125°05.89 W	21/8/98	16:30:00	586 meters

OSU, Torres — Film, Slides

TFX98.08.R455.BB1	44°40.18 N, 125°05.89 W	21/8/98	16:30:00	586 meters

GEOMAR, Rehder	6x 400mL	CH_4
OSU, McManus	6x 250mL	O_2
	6x 50mL	Sufides
	6x 30mL	Total CO_2
	6x 20mL	pH
	6x 30mL	NH_4
OSU, Torres	3x 30mL	^{13}C
	3x 30mL	^{18}O
HSU, deAngelis	18x 125mL	CH_4 oxidation
USC, Hammond	3x 120mL	Radon

TFX98.08.R455.SS	44°40.18 N, 125°05.89 W	21/8/98	16:30:00	586 meters

MBARI, Whaling — Clams collected

TFX98.11.R456.FM1	44°40.18 N, 125°05.89 W	21/8/98	04:39:00	586 meters

OSU, Torres — Film, Slides

SIO, K.Brown — 3 flow meters deployed (E,F,G)

TFX98.11.R456.TB1	44°40.18 N, 125°05.89 W	21/8/98	04:39:00	586 meters

OSU, Torres — transponder beacon was deployed

ROPOS SAMPLES, cont.

TFX98.11.R456.GS1   44°40.18 N, 125°05.89 W   21/8/98   04:39:00   586 meters

USC, Hammond   2 gas samplers were deployed and recovered

*Note: at the end of this dive, the two barrels were lost from the elevator at the surface as the elevator was being brought back on board; the barrel from Cast #2 (BB3) was recovered within the hour and brought up by ROPOS; the barrel from Cast #1 (BB2) was not recovered. Niskin bottles #1 and #3 did not trip, and #4 was empty.

TFX98.11.R456.BB3   44°40.18 N, 125°05.89 W   22/8/98   22:20:00   586 meters

GEOMAR, Rehder	3x 200mL	CH_4
OSU, McManuss-Torres	3x 250mL	O_2
	3x 30mL	^{13}C
	3x 30mL	^{18}O
	3x 50mL	Sufides
	3x 30mL	Total CO_2
	3x 20mL	pH
	3x 30mL	NH_4
HSU, deAngelis	3x 3mL	CH_4 oxidation
USC, Hammond	3x 120mL	Radon

TFX98.13.R457   44°40.23 N, 125°05.81 W   23/8/98   00:45:00   590 meters

OSU, Torres   Films, Slides

Search for missing barrel, unsuccessful

TFX98.13.R457.CC1   44°40.23 N, 125°05.81 W   23/8/98   12:30:00   606 meters

MBARI, Whaling   Clams collected

TFX98.15.R457   44°40.23 N, 125°05.81 W   23/8/98   15455:00   606 meters

OSU, Torres   Films, Slides

ROPOS SAMPLES, cont.

TFX98.15.R458 44°40.23 N, 125°05.81 W 23/8/98 15:45:00 606 meters

OSU, Torres Search for lost barrel

TFX98.15.R458.FM 44°40.23 N, 125°05.81 W 23/8/98 15:45:00 606 meters

SIO, Brown Flow meters A, C deployed

TFX98.15.R458.CC2 44°40.23 N, 125°05.81 W 23/8/98 15:45:00 606 meters

MBARI, Whaling Clams corral replaced

TFX98.17.R459.TB2 44°40.18 N, 125°05.89 W 24/8/98 02:45:00 586 meters

OSU, Torres recover transponder beacons

TFX98.18.R460.MS1 44°40.32 N, 125°05.81 W 24/8/98 03:45:00 30 meters

NOAA, Butterfield test of manifold sampler

BB=benthic barrel (OSU) FM=flow meter (SIO) CC=clam corral (MBARI)
TB=transponder beacon (OSU) MS=manifold sampler (Butterfield)
SS=suction sampler (ROPOS) TS=titanium sampler (ROPOS)
BS=biology sampler (clams, mats) GS=gas sampler (USC)
PC=pushcore (USC)

Appendix 6
Cruise Participants

TECFLUX 98
CRUISE PARTICIPANTS

				Phone	Fax	email
1. Marta Torres (F)	PI	OSU	Costa Rica	541-737-2415	541-737-2064	mtorres@oce.orst.edu
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9. Steve Colbert (M)	Radon	USC	U.S.			
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20. D. Butterfield (M)	Fluid sampler	NOAA	U.S.	206-526-6722	206-526-6054	butterfield@pmel.noaa.gov
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23. Keith Shepherd (M)	Pilot	ROPOS	Canada	250-363-6332	250-363-6357	shepherd@ropos.com
24. Bob Holland (M)	Pilot	ROPOS	Canada	250-363-6332	250-363-6357	shepherd@ropos.com
25. Mike Dempsey (M)	Pilot	ROPOS	Canada	250-656-0535	250-656-0533	mdempsey@vanisle.net
26. Eric Hagen (M)	Pilot	ROPOS				
27. Keith Trembley (M)	Pilot	ROPOS				
28. Kim Wallace	Pilot	ROPOS				

Appendix 7
Addresses of Participating Research Institutes

Appendix 7: Addresses of Participating Institutions

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Arcata CA 95521

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Scripps Institute of Oceanography
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Doug Hammond
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Los Angeles CA 90089-0740

Biology Department
Western Washington University
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Bellingham WA 98225-9160

Canadian Scientific Submersible Facility
c/o Institute of Ocean Sciences
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Carl Katsu
Center for Astrophysics
Harvard College Observatory
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MBARI
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NOAA/PMEL
Hatfield Marine Science Center
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Newport OR 97365-5258

Appendix 8

Abstract Submitted to AGU

Active gas discharge resulting from decomposition of gas hydrates on Hydrate Ridge, Cascadia Margin.

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A massive release of methane on the Cascadia Hydrate Ridge was documented during a ROPOS program in August 1998, consistent with previously reported observations in 1996. An extensive survey of the seafloor revealed that the seeps lie within a narrow band trending 109 degrees. This feature parallels larger mounds imaged by Seabeam as well as larger structures of the accretionary prism such as the Daisy bank. The area of intense bubbling is characterized by extensive bacterial mats. Large clam fields were observed ten's of meters away from the gas seeps. A third province with carbonate blocks but no clams or bacterial mats was mapped approximately 200 meters away from the seeps. To constrain fluid flow through the sediments, we deployed 8 osomotic flow meters. The areas of gas discharge are discrete and highly focussed within conduits with an approximate cross-sectional area of 5 cm2. We estimate the gas flow rate to be on the order of 5 liters/minute. While the subsurface plumbing is unknown, the high flow rate of the sampled gas seep suggests a very short transit time from the gas source (presumably the base of the BSR at 70 mbsf) to the sea

floor. The Rn/CH4 ratio in gas samples collected from the gas vents is very high, approximately 50 dpm/liter (stp) CH4. Using these values, we estimate that the time required for the fluids to transit 70 m is approximately 1 hour. To further constrain the nature of the discharging fluids, we will analyze samples for their elemental and isotopic composition. Methane hydrate should be stable at the temperature and pressure conditions at the seafloor on Hydrate Ridge. Indeed, solid hydrate was observed to form within the gas samplers as well as on the camera itself, supporting the conclusion that methane is rapidly transported to the seafloor from beneath the BSR within discrete conduits, most likely separated from significant amounts of pore water. When discharged at the seafloor, some of the methane precipitate as hydrate and some continues to rise within the water column. Bubbles were observed with the ROV up to 50 meters above the seafloor. This methane generates a plume in the water column, which was first documented during the 1996 GEOMAR survey. The most pronounced methane plumes observed during 1998 occur nearest to the active discharge sites, where methane concentrations up to 800 nmol/l were recorded.