# Operation Report
# of
# Sakhalin Slope Gas Hydrate Project 2011,
# R/V Akademik M. A. Lavrentyev Cruise 56

August 8 - 28, 2011

Vladivostok – Korsakov - Sakhalin Slope – Korsakov - Vladivostok


***Edited by***

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# 1. INTRODUCTION

## 1.1. Tectonic and Geological Setting of the Eastern Sakhalin Slope

*B. Baranov, Y.K. Jin, A. Obzhirov, H. Shoji*

Eastern Sakhalin slope is a transitional zone between the Okhotsk Sea and continent; it represents an area of dynamic exchange between land, sea and airspace. The majority of sediments transported from land mainly by Amur River deposits in this zone. Therefore the slope represents a reservoir of solid sedimentary matter; along with it the slope serves as a source of fluids and gas, particularly methane. Continental slope of the Sakhalin Island is located near present-day plate boundary. It gives opportunity to regard it as an active continental margin of shear type. So, Eastern Sakhalin slope represents a river-dominated margin covering both deep water and shallow water in an active margin setting.

### Slope morphology

Eastern Sakhalin slope deepens towards the central Okhotsk Sea. It bounders with different structural elements of the Okhotsk Sea bottom; they are (in south-north direction): Kurile back-arc basin, Academy of Sciences and Institute of Oceanology Rises, Deryugin Basin and Staritsky Trough (Fig. 1.1.1).

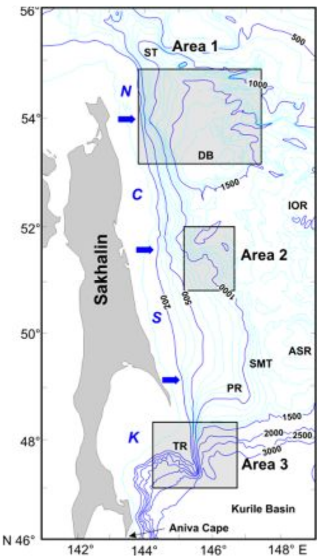


Fig. 1.1.1. Bathymetric map of the Eastern Sakhalin slope and location of the study areas (grey numbered rectangular). Arrows indicate the boundaries between slope segments: K=Kurile, S=Southern, C=Central, N=Northern. Contour interval is 100 m and 500 m for the areas to the north and south from Terpeniya Ridge, correspondently. Abbreviations: TR=Terpeniya Ridge; PR=Polevoy Rise; SMT=Shmidt Trough; ASR=Academy of Sciences.

Eastern slope relief (excluding its segment adjacent to Kurile Basin) is rather simple and homogeneous. Nevertheless some regular variations in its morphology are observed in south-north direction. First of all they are connected with change of slope width, its form and inclination angles; it is distinctly seen even on small-scale bathymetric maps. These changes occur not gradually but rather abruptly within two areas (near 51°30' and 54° N), which subdivide the eastern slope into several segments. The segments include: Kurile part of the slope from Aniva Cape to Polevoy Rise, Southern part of the slope from Polevoy Rise to 51°30', Central part of the slope from 51°30' to 54° and Northern part of the slope from 54° to Staritskiy Trough (Fig. 1.1.1).

Study area 1 covers Northern segment and northern part of Central segment, area 2 locates near by boundary between the Central and Southern segment, and area 3 locates within the Kurile segment (Fig. 1.1.1).

## Basement structure and sediment thickness

Large area of basement subsidence exists to the east from Sakhalin Island. This area continues along slope on distance of 800 km with width of 200 km and includes four troughs (Kharakhinov, 1996; Sergeev, 2004). The biggest among them corresponds to shelf and slope adjacent to Derugin Basin in the bottom relief. This through is filled by sediments with thickness more than 9 km. Other smaller troughs within this subsidence area locate more to the south and are separated from each other by basement heights. Thickness of sediments in these troughs is from 6 up to 9 km.

Study area 1 corresponds to the biggest trough; study area 2 locates under one of the basement heights with sediments thickness of 3-4 km. Study area 3 is in Kurile Basin slope where the sediments thickness increases up to 5 km toward basin.

## Faults system

Obtained data in framework of KOMEX, CHAOS and SSGH projects (*Baranov et al., 2008*) revealed a system of conjugate faults, which in some cases come out on the surface. It appears as several scarps with height 50-100 meters trending in NW-SE and NE-SW directions and may be traced in depth interval 250-1100 meters. These scarps are undoubtedly a surface manifestation of the faults, which is distinctly seen on the seismic profiles obtained during KOMEX, CHAOS and SSGH expeditions. There are several canyons striking in the north-eastern direction; their origin has fault nature as well. The largest fault called Lavrentiev Fault (*Baranov et al., 2005)* separates Northern segment from Southern one.

Second supposed faults system is located on latitude 51°30'N. It was noted in relief description that there is a N-E- striking depression on small-scale map (see Fig. 1), which may be limited by faults. The character of displacements along the faults cannot be defined due to absence of detailed bathymetric map of this area and seismic sections across it. Lavrentiev Fault and second supposed faulting zone represent boundaries between slope segments mentioned above (see Fig. 1).

## Gas seepage distribution

Expressions of gas seepage observable within eastern Sakhalin slope in seismo-acoustic data include hydroacoustic anomalies (gas flares) in the water column, sonar structures, pockmarks and mounds on seabed, and gas chimneys subbottom.

Hydroacoustic anomalies data are used to clarify general pattern of seeps distribution on the eastern Sakhalin slope. These data were obtained in hydroacoustic survey, which have been conducting during all cruises both on study areas and on the transit from harbor to study areas (*Salomatin, 2003; 2005; 2006; Salomatin et al., 2008*). Though hydroacoustic survey is performed along separate tracks and is not an swath mapping, being space enough it gives an idea of hydroacoustic anomalies distribution. Existence of hydroacoustic anomalies in its turn is the most convincing evidence of submarine seepage of gas-containing fluids.

Hydroacoustic anomalies distribution on the eastern slope of Sakhalin Island is irregular (Fig. 2A). From the total number of about 800 gas flares only five ones were registered within its Kurile segment in depth interval 150-730 meters; there are no flares at all on the southern segment. The central segment is characterized by irregular HA distribution. There are isolated HA within the southern part and they are present only on the shelf there. In the northern part of the segment beginning from 52º50' N the number of HA dramatically increases and maximum concentration is observed in the northern segment. Within this part of the slope HA occur at depths from less than 200 up to 1200 meters and deeper.

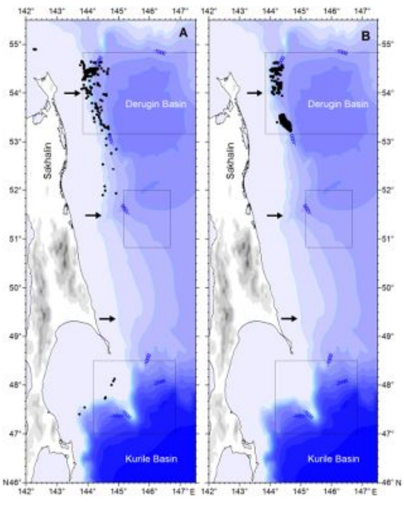


Fig. 1.1.2. Distribution of the gas flares (A) and sonar structures (B) shown by black dots. Rectangulars indicate study areas. Arrows mark segment boundaries. Contour interval is 500 m (GEBCO map).

A question arises thereupon: does the observed pattern reflects real HA distribution or it is an artifact connected with hydroacoustic survey density? In fact hydroacoustic survey tracks is closer spaced in northern segment (the main object of SSGH project) as compared with more southern segments. From the other hand the differences in the space closeness of ship tracks within the central and southern segments are insignificant. Nevertheless rather big number of HA were recorded in the northern part of central segment and they are isolated or absent in its southern part. It gives opportunity to assume that observed pattern is not an artifact but reflects the real HA distribution.

From the other hand large distribution of the pockmarks within southern area *(Baranov et al., 2008)* give us opportunity to suggest expulsion of gas some time ago. Does this process continue or not is one of the targets of this cruise.

Side-scan sonar investigations were carried on within Northern segment and Central segments (its northern part) (Reports). These investigations show that northern and southern segments differ from each other both by density of seepages per square unit and by character of their distribution (Fig. 1.1.2B). Average density of seepages within whole studied area in the northern segment is 1SS per 10 km$^2$; in the southern segment it is 1SS per 1 km$^2$, i.e by an order more. It is so because on northern segment seepages are not randomly distributed in this area, but are concentrated in several more or less isolated fields, separated by areas where seepage structures are absent.

Such pattern is first of all connected with conduits distribution. Tectonic faults having north-western and north-eastern strikes and most likely represented by strike-slip faults may serve as conduits. Besides, the seeps are concentrated near fissures of different type, which has appeared in the body of submarine landslide (central part of the northern segment), and near the erosion channel (northern part of the northern segment).

In the southern segment seepages are located uniformly filling nearly whole square of the studied area without any essential interspaces. Isolines of their density have tendency to be oriented in NW and NE directions; i.e. have the same strikes as the faults distinguished within the northern segment. In the southern segments no faults are distinguished, but we suppose that a system of fissures exists here. These fissures are indistinguishable on the seismic sections because they are masked by gas chimneys serving as conduits for seepages.

As far as strike of supposed fissures and faults' orientation coincide they apparently originated in a single stress system. It also may be supposed that slope failure in its northern segment lead to dropping of sedimentary cover load and transformation of fissures into faults. At the same time part of the fissures still exist within the northern segment; evidence of it is existence of linear seepages, which we call fissure seepages.

## 1.2. SSGH Project

*H. Shoji, Y. K. Jin, A. Obzhirov, B. Baranov*

### 1.2.1. Framework of SSGH Project

The Sakhalin Slope Gas Hydrate Project (SSGH Project) 2007 – 2012 is an international collaboration effort among scientists from Japan, Korea and Russia to investigate on natural gas hydrates accumulated on a continental slope offshore Sakhalin Island. Main objectives of this project include:

(1) To characterize gas hydrates and gas hydrate-bearing sediments in Sakhalin Slope,
(2) To understand gas migration and gas hydrate formation mechanisms at methane seep areas,
(3) To trace methane migration from gas hydrate system to atmosphere through water column and its impact to global warming
(4) To understand process of gas hydrate destabilization and its influence on slope failure as one of geological hazards and
(5) To establish a monitoring network for a long-term gas hydrate stability variation.

Participating Institutes:

Kitami Institute of Technology (KIT), Japan
Korea Polar Research Institute (KOPRI), Korea
V. I. Il'ichev Pacific Oceanological Institute FEB RAS (POI), Russia
P. P. Shirshov Institute of Oceanology RAS, Russia

Members of the Steering Committee of the SSGH Project:

Hitoshi Shoji,
New Energy Resources Research Center, Kitami Institute of Technology, Japan
Young Keun Jin,
Korea Polar Research Institute, KORDI, Korea
Anatoly Obzhirov,
Laboratory of Gasgeochemistry,
V. I. Il'ichev Pacific Oceanological Institute, FEB RAS, Russia
Boris Baranov
P. P. Shirshov Institite of Oceanology, RAS, Russia

The steering committee members agreed to discuss and determine (1) tasks for participating institutes on both field and laboratory investigations, (2) field operation plans including details of survey techniques, study site selections, schedules, participants and cost-shared budgeting, (3) publication procedures including data sharing, personnel exchanges and co-authorships and (4) new research plans including new subjects and participants well in advance for the project operation to our mutual scientific interests and merits.

### 1.2.2. Goals of SSGH-11 Project

We have obtained a lot of remarkable results in the northern Sakhalin continental slope from the CHAOS project (2003, 2005, 2006); lots of gas flares in the water column, many gas fluid seepage structures on the seafloor, gas hydrate samples including massive gas hydrate chunk (about 35 cm thick) near the seafloor, and gas hydrate-related structures in gas hydrate-bearing sediments. These results encourage us to continue and expend our research activity in the Sakhalin continental margin.

As CHAOS project with such fruitful results ended in 2006, SSGH Project 2007-2012 was launched as a new project in 2007. First two year cruises in 2007 and 2008 were totally devoted to areal mapping of seafloor and water column structures related to gas/fluid seeping phenomena in the gas hydrate area on the northeastern continental slope off Sakhalin Island, Okhotsk Sea. Further study is continued by sea sediment coring to understand the formation mechanism of gas hydrate in terms of gas, water and sediment characteristics and biogeochemical processes taking place near sea bottom environment.

Research goals of the SSGH-11 expedition included:

1. Core sampling for gas, water and sediment characteristics at gas/fluid seepage.
2. Detailed bathymetry around gas/fluid seep areas..
3. Detection of gas chimney above and below BSR
4. Detection of gas flare in the water column emitted from gas/fluid seepages
5. CTD water sampling for sea water and bottom conditions

### 1.2.3. Field Operation of SSGH-11 Project

Field operation of SSGH-11 project was conducted as the 56th cruise of R/V Akademic M.A. Lavrentyev (Fig. 1.2.1). This cruise was carried out from August 8 to 28, 2011. R/V Lavrentiev sailed with the following ship route; Vladivostok (August 9)-Korsakov (August 12)-the study area (August 13-24)-Korsakov (August 25)-Vladivostok (August 28) (Fig. 1.2.2).

Twenty-seven scientists took part in cruise including Japanese (Kitami Institute of Technology), Korean (Korea Polar Research Institute) and Russian (V. I. Il'ichev Pacific Oceanological Institute FEB RAS and P. P. Shirshov Institute of Oceanology RAS) participants (Appendix 4.2). SSGH 2011 cruise was organized by POI.

During this expedition, three working areas were separately investigated (Fig. 1.2.3). Working area 1 is covered by side-scan sonar survey during SSGH-07 and -08 cruises. Working area 2 includes a pockform area. To get information on gas seep and hydrate formation in the South, area

3 was targeted at Terpeniya Ridge.

Working area 1 is located to the north and south of the Lavrentyev Fault. Lots of gas flares, pockmarks and gas chimney structures were found in the previous expeditions (ref. on Reports of KOMEX, CHAOS and SSGH). However this expedition is specially designed to fill the data-vacancy.

During the expedition, and 119 gas flare images were obtained, and 18 sediment cores were retrieved.


Fig. 1.2.1. R/V Akademic M.A. Lavrentyev

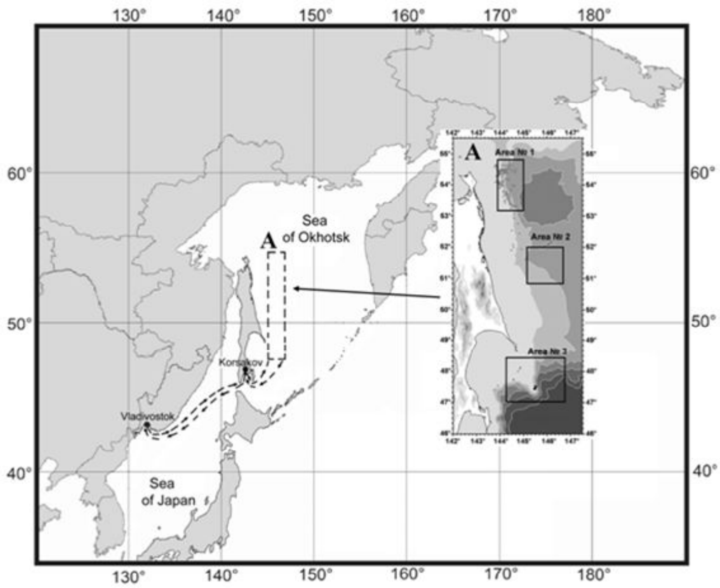


Fig. 1.2.2. Cruise route of SSGH-09 expedition

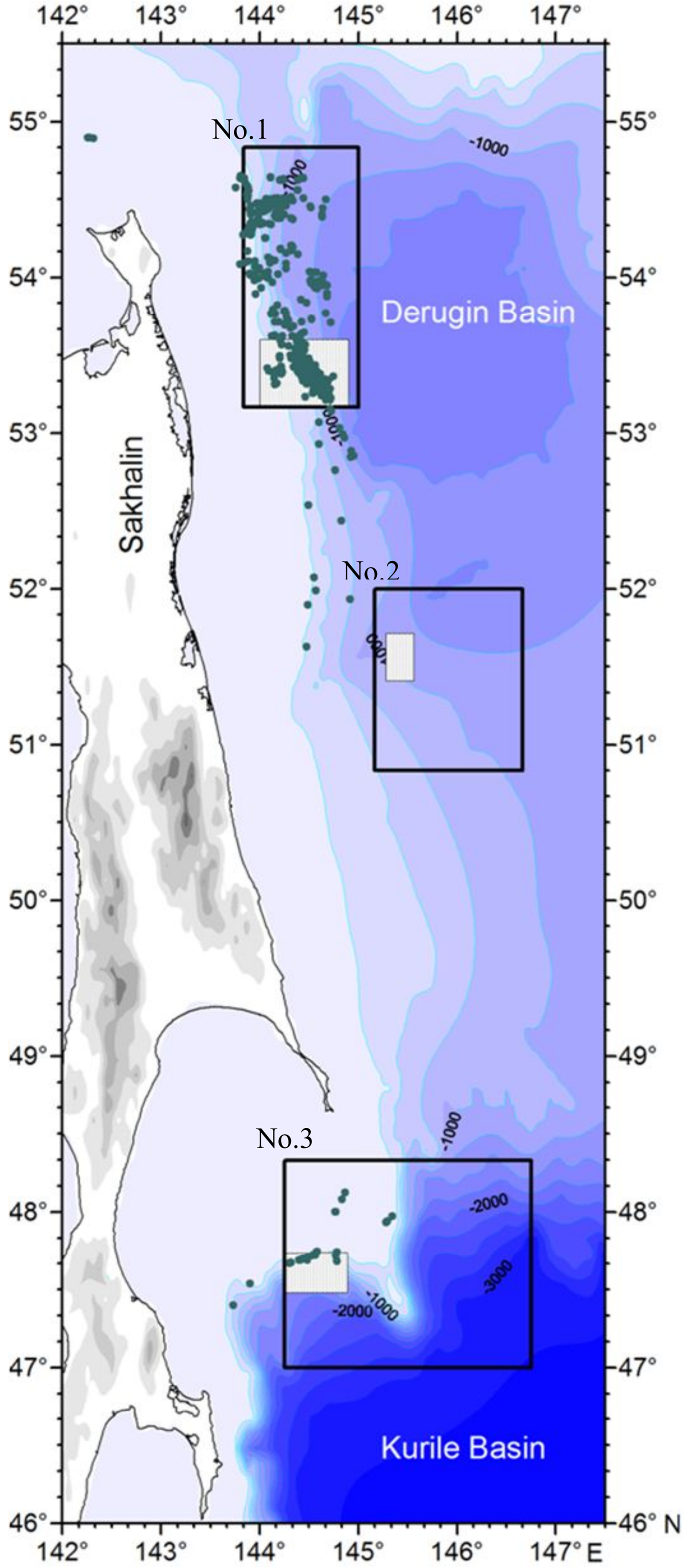


Fig. 1.2.3. Study areas of SSGH-11 expedition.

### 1.2.4. Survey Permissions and Supports

Russian Side

R/V Akademik M. A. Lavrentyev Cruise 56 (8 – 28 August, 2011) was organized in accord to the following official documents in Russian side:

1. Permission from Russia Federal Agency for Science and Innovations 29 June, 2011, No 72 to provide expedition in the Sakhalin North-East shelf and slope of the Okhotsk Sea in accord to expedition Program and Agreement of SSGH Project in 2011 from 8 to 28 August, 2011.
2. Program expedition R/V Akademik M. A. Lavrentyev Cruise 56 (8 – 28 August, 2011) from POI FEB RAS is confirmed Presidium of FEB RAS of 18 July, 2011.
3. Orders to provide expedition R/V Akademik M. A. Lavrentyev Cruise 56 (8 – 28 August, 2011) from POI (20 July 2011, No.40-e) and from Presidium FEB RAS (22 July 2011, No.16121-52H).
4. Agreement about joint scientific researches and to cover expenditures to carry out expedition in the Okhotsk Sea (21 days) using R/V 'Akademik M.A. Lavrentyev', to study submarine gas hydrates at the Okhotsk Sea among POI FEB RAS, KOPRI and KIT (Signatures: May 31, 2011).

Korean Side

This field investigation is supported by the followings in Korean side:

1. Korea Polar Research Institute grant PE11240

Japanese Side

This field investigation is supported by the followings in Japanese side:

1. Kitami Institute of Technology
2. The Japan Society for the Promotion of Science KAKENHI 23254008
3. The Japan Society for the Promotion of Science KAKENHI 21360219
4. The Japan Society for the Promotion of Science KAKENHI 22540485

## 2. GEOPHYSICAL SURVEYS

### 2.1. Bathymetric and Seismic Surveys

*B. Baranov, Y. K. Jin, V. Prokudin, A. Koptev, E. Sukhoveev*

Bathymetric investigations conducted during the 56 Lavrentyev cruise (SSGH-11 expedition) were concentrated on two main targets: 1. mapping the sites in the areas 1-3 with aim to obtain data about specific bottom features connected with the seepage, 2. mapping the major morphological features of the eastern Sakhalin slope for updating of the existing bathymetric map. In addition to the bathymetric surveys were necessary to choose the location for sediments sampling on sites (pre-sampling survey). The bathymetric survey carried on along the tracks combining in the orthogonal network for investigations of the seepage site and along the seismic line. Bathymetry survey was also performed continuously during whole working time on sampling stations and on the approaches to them. The total length of the bathymetric tracks was equal 2205 km in the areas under investigation. The location of the bathymetric profiles and examples of bathymetric map are shown on Fig. 2.1.1.

Seismic surveys, carried during the cruise, were used for: 1. study the upper part of the sediment section, 2. detection of the gas chimneys, 3. determination of the BSR location and 4. identification of the tectonic structure. Study areas were located on the three distinct sites: western slope of Derugin basin and Terpeniya Ridge. The total length of the seismic profiles was equal 887 km. 33 profiles were obtained during the cruise; these profiles were stored as 17 files (041_1-056_1) with extension SEGY (data format - I2). The location of seismic profiles is shown in Figs 2.1.2 and 2.1.3. Table 2.1.1 contains profile coordinates.

### 2.1.1 Equipment

Bathymetric investigations were conducted using ship-mounted deep-water echosounder ELAC LAZ-72 E-V. Its technical characteristics are:

| | |
|---|---|
| Operating frequency | 12 kHz |
| Nominal power in impulse | 2 kWt или 200 Wt |
| Beam polar pattern | 10º x 10º |
| Duration of impulse | 0.3, 1 or 3 ms |
| Range of measurements | 0 – 15000 m |
| Depth of underwater sound projector | 4.5 m |

Standard accuracy ± 1%

Reflected echo signal after nomination and filtering is transformed by digitizer ELAC STG-721 and is passed to the user in accordance with protocol RS232 without time reference. Navigation reference was fulfilled using 12-channel navigator receiver GARMIN GPSMap 420s with support of WAAS technology. Estimated accuracy of positioning (HDOP) did not exceed 2-5 m during whole cruise. Every second the receiver produces data on coordinates and time on the display into the outer channel in accordance with protocol RS-232.

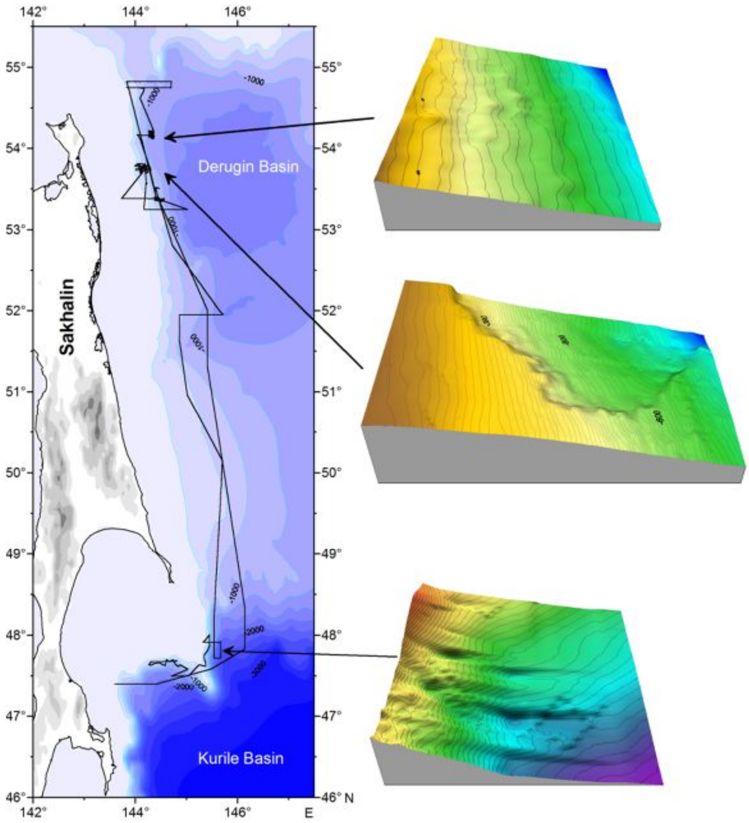


Fig. 2.1.1. Bathymetric tracks of the 56-th RV Akademik Lavrentyev cruise and 3D examples of the bathymetric maps.

Data from satellite navigator receiver and echo-sounder are synchronized and registered by specially designed program, operating on usual personal computer. As a result each measurement of depth is uniquely tied to time and receives exact geographic coordinates. Re-calculation of coordinates to the form, convenient for further processing, is performed simultaneously. Complete bathymetric information is available immediately after each echosounder line. Sound velocity was accepted as 1500 m/s during registration. Corrections for salinity and pressure were not applied. Cycling of measurements was determined by depth range and was from 2 to 6 seconds.

Sparker “Sonic 4M” (energy - 4000 J) was used for wave excitation during the seismic surveys; single-canal seismic streamer (length of active section is 46 m and it contains 160 hydrophones, each sensitivity 160 mcV/Pa) was applied for signal registration. Distance “source – receiver” was equal 75 m, distance “antenna GPS – reception point” - 100 m. The recording system was interfaced with the PC. Equipment has been used for registration: complex developed by laboratory seismic research POI FEB RAS (contains analog amplifier signals from seismic stream, analog bandpass filter and 16 capacity ADC, analog-to-digital converter); registration program works under DOS system control. The profiles run on speed 5 – 5.5 knots, excitation interval was 8 sec, thereby shot interval was equal about 22-23 m. Sample rate was 200 mcsec, record length was equal 500 msec. Time of registration interval was chosen in correspondence with the sea depth. 33 profiles were obtained during the cruise; these profiles were stored as 19 files with extension SEGY (data format - I2). Data registration carried out in frequency interval 210 – 1500 Hz.

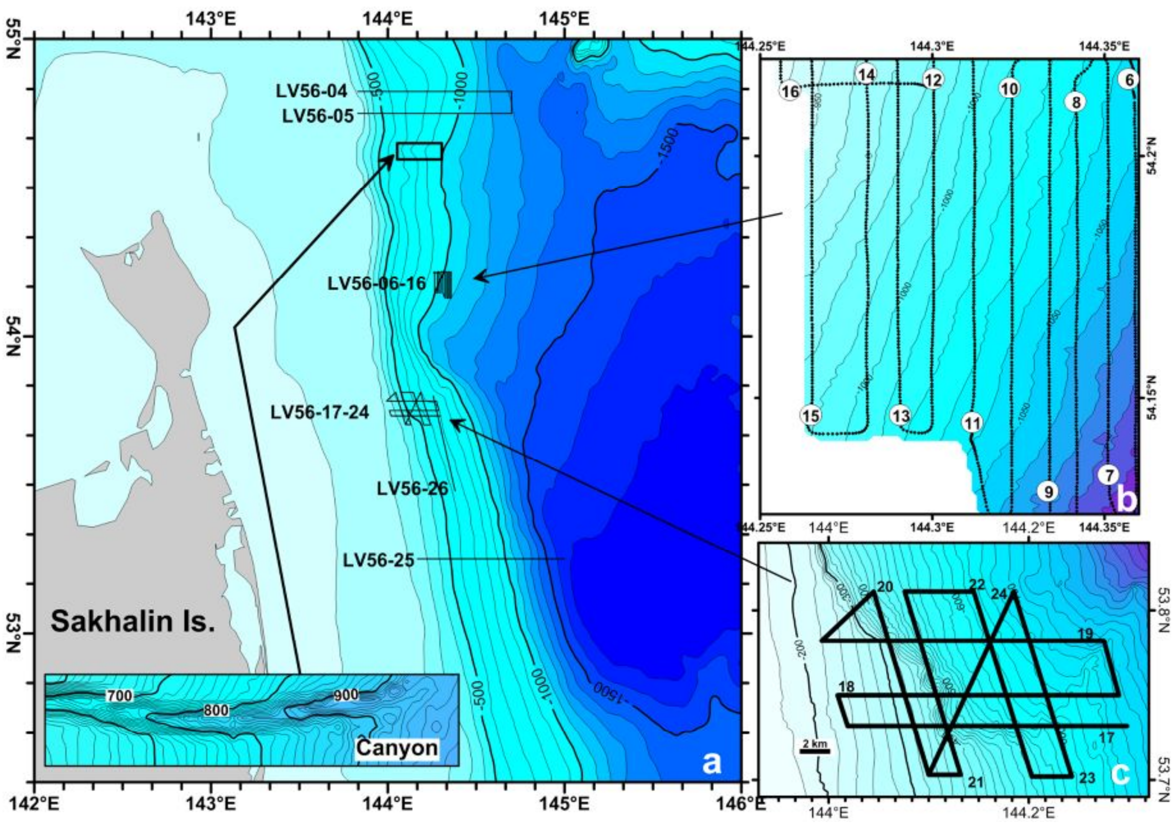


Fig. 2.1.2. Location of the seismic profiles and their number in study areas 1 (a), area of seepage field 9 (b), and Lavrentyev Fault Zone (c). Inset on Fig.1a shows the bathymetry of the canyon, which is northern boundary of the Northern segment. Contour interval is 10 m.

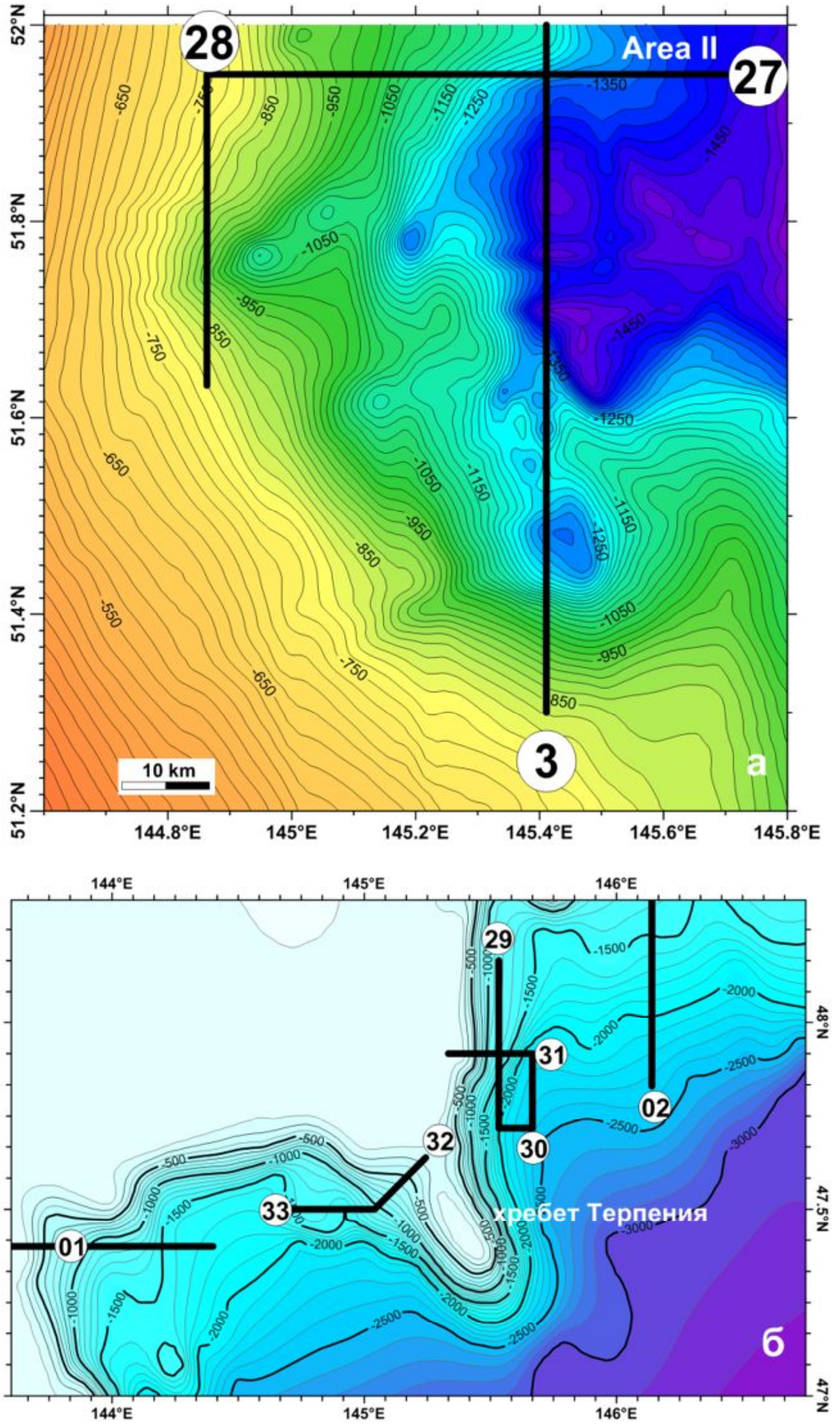


Fig. 2.1.3. Location of the seismic profiles and their numbers in study area 2 (a) and study area 3 (b).

Table 2.1.1. List of files and corresponding seismic profiles

| **Date: (2011, August)** | **Profile, №** | **File name** | **Time (GMT)** | | **Length** (km) | **Start** | | **End** | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Start | End | | Latitude, N | Longitude, E | Latitude, N | Longitude, E |
| 13 | LV56-S01 | 041_1 | 10:36 | 16:31 | 59,5 | 47°23, 996 | 143°36,726 | 47°23, 999 | 144°24,163 |
| 14 | LV56-S02 | 042_1 | 00:19 | 05:44 | 54,5 | 47°50,459 | 146°08,379 | 48°19, 910 | 146°08,392 |
| 14 | LV56-S03 | 043_1 | 23:15 | | 76,6 | 51°18,445 | 145°24,674 | | |
| 15 | | | | 06:48 | | | | 51°59,815 | 145°24,662 |
| 16 | LV56-S04 | 044_1 | 15:02 | 20:46 | 57,4 | 54°48,786 | 143°49,833 | 54°49,406 | 144°42,261 |
| 16 | S04-S05 | 044_1 | 20:46 | 21:00 | 2,5 | 54°49,406 | 144°42,261 | 54°48,042 | 144°41,987 |
| 16 | S04-S05 (ending) | 045_1 | 21:10 | 21:43 | 5,1 | 54°47,595 | 144°41,910 | 54°44,844 | 144°41,669 |
| 16 | LV56-S05 | 045_1 | 21:43 | 23:03 | 13,8 | 54°44,844 | 144°41,669 | 54°45,011 | 144°28,755 |
| 16 | LV56-S05 (ending) | 045_2 | 23:12 | | 39,6 | 54°44,994 | 144°27,244 | | |
| 17 | | | | 03:08 | | | | 54°44,993 | 143°50,186 |
| 17 | LV56-S06 | 046_1 | 10:34 | 11:29 | 9,4 | 54°12,687 | 144°21,519 | 54°07,584 | 144°21,521 |
| 17 | S06-S07 | 046_1 | 11:29 | 11:32 | 0,4 | 54°07,584 | 144°21,521 | 54°07,610 | 144°21,174 |
| 17 | LV56-S07 | 046_1 | 11:32 | 11:43 | 1,8 | 54°07,610 | 144°21,174 | 54°08,578 | 144°21,068 |
| 17 | LV56-S07 (ending) | 046_2 | 11:53 | 12:35 | 6,8 | 54°09,524 | 144°21,076 | 54°13,169 | 144°20,781 |
| 17 | S07-S08 | 046_2 | 12:35 | 12:38 | 0,5 | 54°13,169 | 144°20,781 | 54°12,960 | 144°20,509 |
| 17 | LV56-S08 | 046_2 | 12:38 | 13:37 | 10,2 | 54°12,960 | 144°20,509 | 54°07,432 | 144°20,490 |
| 17 | S08-S09 | 046_2 | 13:37 | 13:41 | 0,5 | 54°07,432 | 144°20,490 | 54°07,460 | 144°20,065 |
| 17 | LV56-S09 | 046_2 | 13:41 | 14:44 | 10,8 | 54°07,460 | 144°20,065 | 54°13,282 | 144°20,035 |
| 17 | S09-S10 | 046_2 | 14:44 | 14:50 | 0,7 | 54°13,282 | 144°20,035 | 54°13,122 | 144°19,416 |
| 17 | LV56-S10 | 046_2 | 14:50 | 15:50 | 10,3 | 54°13,122 | 144°19,416 | 54°07,567 | 144°19,361 |
| 17 | S10-S11 | 046_2 | 15:50 | 16:02 | 1,6 | 54°07,567 | 144°19,361 | 54°08,342 | 144°18,747 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 17 | LV56-S11 | 047_1 | 16:09 | 17:01 | 8,5 | 54°08,612 | 144°18,698 | 54°13,205 | 144°18,701 |
| 17 | S11-S12 | 047_1 | 17:01 | 17:07 | 0,7 | 54°13,205 | 144°18,701 | 54°13,185 | 144°18,032 |
| 17 | LV56-S12 | 047_1 | 17:07 | 17:59 | 8,5 | 54°13,185 | 144°18,032 | 54°08,623 | 144°17,973 |
| 17 | S12-S13 | 047_1 | 17:59 | 18:03 | 0,6 | 54°08,623 | 144°17,973 | 54°08,664 | 144°17,440 |
| 17 | LV56-S13 | 047_1 | 18:03 | 18:52 | 8,3 | 54°08,664 | 144°17,440 | 54°13,173 | 144°17,383 |
| 17 | S13-S14 | 047_1 | 18:52 | 18:57 | 0,6 | 54°13,173 | 144°17,383 | 54°13,140 | 144°16,837 |
| 17 | LV56-S14 | 047_1 | 18:57 | 19:46 | 8,3 | 54°13,140 | 144°16,837 | 54°08,652 | 144°16,861 |
| 17 | S14-S15 | 047_1 | 19:46 | 19:54 | 1,1 | 54°08,652 | 144°16,861 | 54°08,663 | 144°15,828 |
| 17 | LV56-S15 | 047_1 | 19:54 | 20:43 | 8,3 | 54°08,663 | 144°15,828 | 54°13,167 | 144°15,897 |
| 17 | S15-S16 | 048_1 | 20:48 | 20:52 | 0,6 | 54°13,210 | 144°15,371 | 54°12,871 | 144°15,454 |
| 17 | LV56-S16 | 048_1 | 20:52 | 21:04 | 2,0 | 54°12,871 | 144°15,454 | 53°12,901 | 144°17,318 |
| 18 | LV56-S17 | 049_1 | 10:40 | 12:33 | 19,1 | 53°43,746 | 144°18,263 | 53°43,985 | 144°00,813 |
| 18 | S17-S18 | 049_1 | 12:33 | 12:46 | 2,0 | 53°43,985 | 144°00,813 | 53°45,074 | 144°00,626 |
| 18 | LV56-S18 | 049_1 | 12:46 | 14:37 | 18,6 | 53°45,074 | 144°00,626 | 53°45,077 | 144°17,585 |
| 18 | S18-S19 | 049_1 | 14:37 | 15:00 | 3,7 | 53°45,077 | 144°17,585 | 53°46,958 | 144°16,398 |
| 18 | LV56-S19 | 049_1 | 15:00 | 16:36 | 16,5 | 53°46,958 | 144°16,398 | 53°46,921 | 144°01,347 |
| 18 | S19-S20 | 050_1 | 16:44 | 17:26 | 6,7 | 53°46,890 | 144°00,785 | 53°48,692 | 144°03,178 |
| 18 | LV56-S20 | 050_1 | 17:26 | 18:40 | 12,7 | 53°48,692 | 144°03,178 | 53°42,090 | 144°06,153 |
| 18 | S20-S21 | 050_1 | 18:40 | 18:55 | 2,1 | 53°42,090 | 144°06,153 | 53°42,327 | 144°08,067 |
| 18 | LV56-S21 | 050_1 | 18:55 | 20:16 | 12,5 | 53°42,327 | 144°08,067 | 53°48,744 | 144°04,547 |
| 18 | S21-S22 | 050_1 | 20:16 | 20:47 | 4,9 | 53°48,744 | 144°04,547 | 53°48,604 | 144°09,020 |
| 18 | LV56-S22 | 050_1 | 20:47 | 22:01 | 12,7 | 53°48,604 | 144°09,020 | 53°42,020 | 144°12,294 |
| 18 | S22-S23 | 050_1 | 22:01 | 22:18 | 2,6 | 53°42,020 | 144°12,294 | 53°42,201 | 144°14,702 |
| 18 | LV56-S23 | 050_1 | 22:18 | 23:34 | 12,7 | 53°42,201 | 144°14,702 | 53°48,717 | 144°11,008 |
| 18 | LV56-S24 | 050_1 | 23:34 | | 13,5 | 53°48,717 | 144°11,008 | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 19 | | | | 00:54 | | | | 53°42,068 | 144°05,865 |
| 19 | LV56-S25 | 051_1 | 11:22 | 16:53 | 55,4 | 53°15,198 | 144°10,061 | 53°14,994 | 145°00,120 |
| 20 | LV56-S26 | 052_1 | 15:06 | 18:45 | 36,5 | 53°47,880 | 144°14,550 | 53°28,791 | 144°22,841 |
| 21 | LV56-S27 | 053_1 | 08:45 | 14:25 | 57,8 | 51°57,098 | 145°42,360 | 51°56,988 | 144°51,713 |
| 21 | LV56-S28 | 054_1 | 14:25 | 17:49 | 34,8 | 51°56,954 | 144°51,687 | 51°38,130 | 144°51,782 |
| 22 | LV56-S29 | 055_1 | 15:02 | 20::03 | 50,5 | 48°10,460 | 145°32,020 | 47°43,211 | 145°32,058 |
| 22 | S29-S30 | 056_1 | 20:08 | 21:03 | 9,3 | 47°43,200 | 145°32,675 | 47°43,233 | 145°40,100 |
| 22 | LV56-S30 | 056_1 | 21:03 | 23:11 | 22,0 | 47°43,233 | 145°40,100 | 47°55,112 | 145°39,912 |
| 22 | LV56-S31 | 056_1 | 23:11 | | 24,7 | 47°55,112 | 145°39,912 | | |
| 23 | | | | 01:38 | | | | 47°54,999 | 145°20,051 |
| 23 | LV56-S32 | 057_1 | 06:05 | 08:16 | 21,7 | 47°38,226 | 145°14,871 | 47°30,049 | 145°02,467 |
| 23 | LV56-S33 | 057_1 | 08:16 | 10:36 | 24,2 | 47°30,049 | 145°02,467 | 47°29,996 | 144°43,119 |

Remark: LV56-S01 – LV56-S33 mark the profiles; S04-S05 - S29-S30 mark the transition from one profile to another one.

### 2.1.3 Results

Six profile sites located within study areas 1-3 were investigated during the LV56 cruise. Four sites in Study area 1 are located to the north from canyon, in seepage field F9, in Lavrentyev Fault Zone and to south from LFZ (see Fig. 2.1.2). Fifth site locates on boundary between Central and Southern segments (area 2) and sixth site locates in Kurile segment, area 3 (see Fig. 2.1.3). The data obtained will be considered for each study area, separately.

#### 2.1.3.1 Study area 1

Morphology and sediment structure of the sites investigated inside of the Study area 1 are strongly different each. The most northern site locates to the north from the channel crossing the slope (see Fig. 2.1.2a).

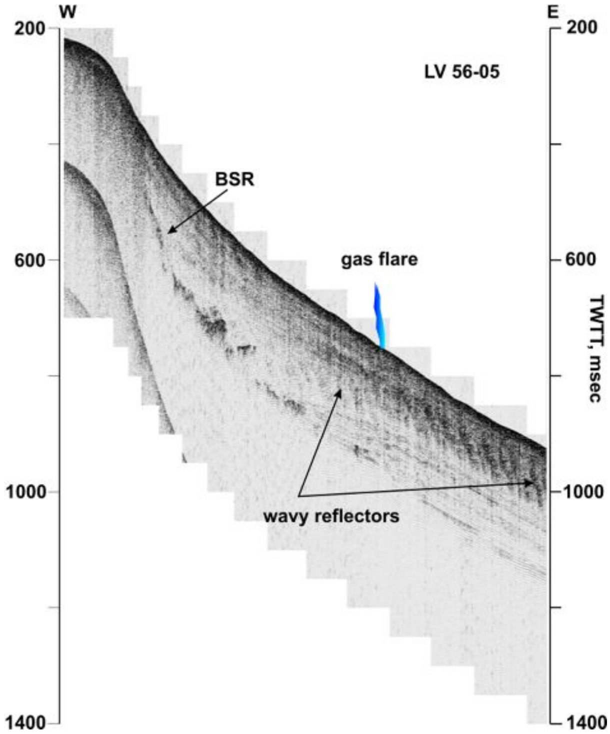


Fig. 2.1.4. Part of seismic profile LV56-05 showing location of the BSR and gas flare. See Fig. 2.1.2a for location.

### *Northern part*

Two crossings of the slope in depth interval 200-1300 m were worked out to the north from the canyon. Both profiles have similar sections with penetration into sediments down to 200 msec from the bottom surface. Sedimentary cover is stratified; numerous reflectors are observed in it. BSR is distinctly seen on the profiles, especially on profile LV56-04; it may be traced down to depth 1100 msec. Starting with depth 600 m the BSR abruptly rises to the bottom surface cutting off sedimentary reflectors and touches the bottom at depth 300 m. On one of the profiles gas flare was registered which it is located above wavy reflectors; top of the reflectors is located at depth about 800 msec (Fig. 2.1.4). Similar reflectors are also observed on profile LV56-04. Such wavy reflectors in the section earlier were interpreted as buried sedimentary waves (Wong et al., 2003).

Main difference between sedimentary sections of these profiles and seismic profiles obtained in the area to the south from the canyon is absence of structures like gas chimneys. This fact along with the fact that only one gas flare was registered here may justify that gas seepage here is less active as compared with the areas to the south from the canyon.

***Seepage structure field F9, north of Lavrentyev Fault Zone.***

To the north of Lavrentyev Fault Zone, as it was shown before (Baranov et al., 2008; Jin et al., 2011), the seepage structures are grouped in more or less isolated fields. Twelve fields (F1-F12) including 202 seepage structures were distinguished; only several structures are located outside these fields. The amount of seepage structures in each field varies from 3 up to 39. Their density within the fields changes from one structure per km$^2$ up to three structures per km$^2$; average density of seepage structures throughout whole sonar mapped area is one structure per 10 km$^2$. Eleven seismic profiles with length 8.5-10 km and distance between profiles 1 km (see Fig. 2.1.2b) were obtained to study the structure of upper part of sedimentary cover in the biggest seepage structures field F9.

High-amplitude reflector located at depths over 100 msec from the bottom surface in the northern part of the area and up to 50 msec in its southern part may be distinguished on all profiles (Figs. 2.1.5). Below this horizon the reflections are absent or there are short inclined reflectors; the last may be connected with refraction caused by rough surface of high-amplitude reflector.

Two sedimentary units may be distinguished on seismic profiles above high-amplitude reflector (Fig. 2.1.5). Lower sedimentary unit is characterized by presence of reflecting boundaries and its thickness gradually decreases from north to south so that in the south its lower reflecting horizons pinch out on the surface of high-amplitude reflector. Top surface of this sedimentary unit in general is conforming to the high-amplitude reflector's surface. In the second (upper) sedimentary unit reflecting boundaries are less distinct; its thickness in direction from north to the south remains constant.

The seepage structure field F9 is located in the slope area which suffered slope failure accompanied by landslides origination as it was reported earlier (Wong et al., 2003). So it may be rather confidently supposed that top of high-amplitude reflector corresponds to surface of one of the slides.

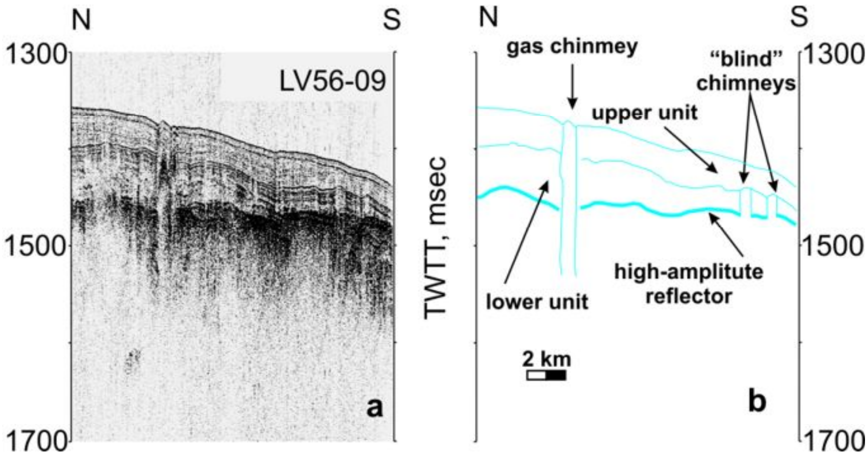


Fig. 2.1.5. Seismic profile LV56-09 showing structure of the upper sedimentary cover of the seepage field F9 (a) and its interpretation (b). See location in Figs. 2.1.2b and 2.1.6.

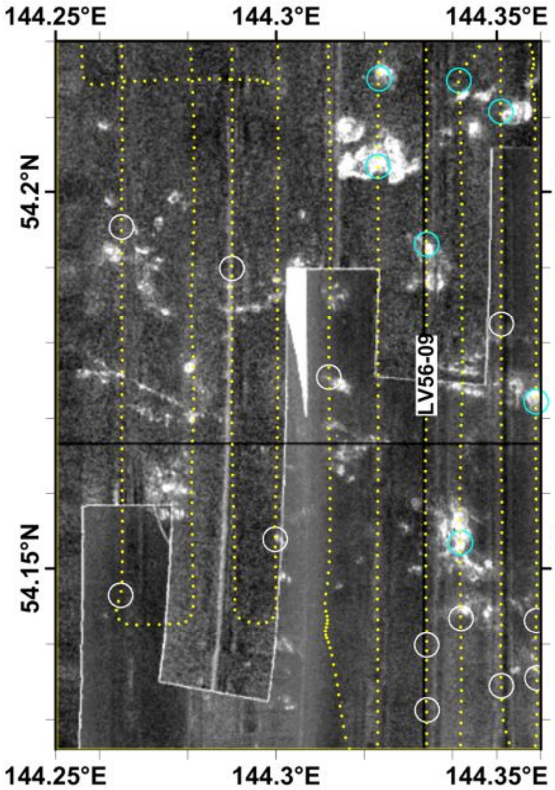


Fig. 2.1.6. Side-scan sonar image of the seepage structure field F9, location of the track lines (yellow dots) and gas chimneys. Blue open circles indicate distinct gas chimneys that reach the sea floor, white open circles mark "blind" or indistinct chimneys.

Several gas chimneys were observed on the profiles. Some of them reach the surface forming small mounds or depressions (pockmarks?) and the others terminate in sediments (see Figs. 2.1.5 and 2.1.6). Gas flares were registered only above one-half of total amount of gas chimneys. There is a good correlation between gas chimneys and seepage structures (Fig. 2.1.6).

### *Lavrentiev Fault Zone*

Lavrentyev Fault Zone (LFZ) is one of the most remarkable features of the eastern Sakhalin slope. This zone was crossed by three seismic profiles during cruises carried on in frame of German-Russian Project KOMEX, but for the first time it was distinguished in 31 cruise of RV Lavrentyev, CHAOS Project, 2003 (Matveeva et al., 2005). Later its south-eastern part was mapped by multibeam echosounder during RV Sonne, cruise SO-178 (Dullo et al., 2004) and additional bathymetric and seismic surveys were carried on there in frame of Project CHAOS 2, 2005, and SSG.

These investigations have shown that Lavrentyev Zone consists of three faults; they are expressed in relief as scarps with height up to 150 m. First scarp has NE-SW strike and is located in depth interval 350-1200 m. On 1200 m contour line it conjugates under nearly right angle with second scarp; the last strikes in NW-SE direction and is distinguished in relief up to contour line 600 m. Third scarp is located in upper part of the slope and its NW-SE orientation was supposed. One of the tasks of 56-th Cruise of RV "Akademik Lavrentyev" was to clarify character of its conjugation with the first scarp.

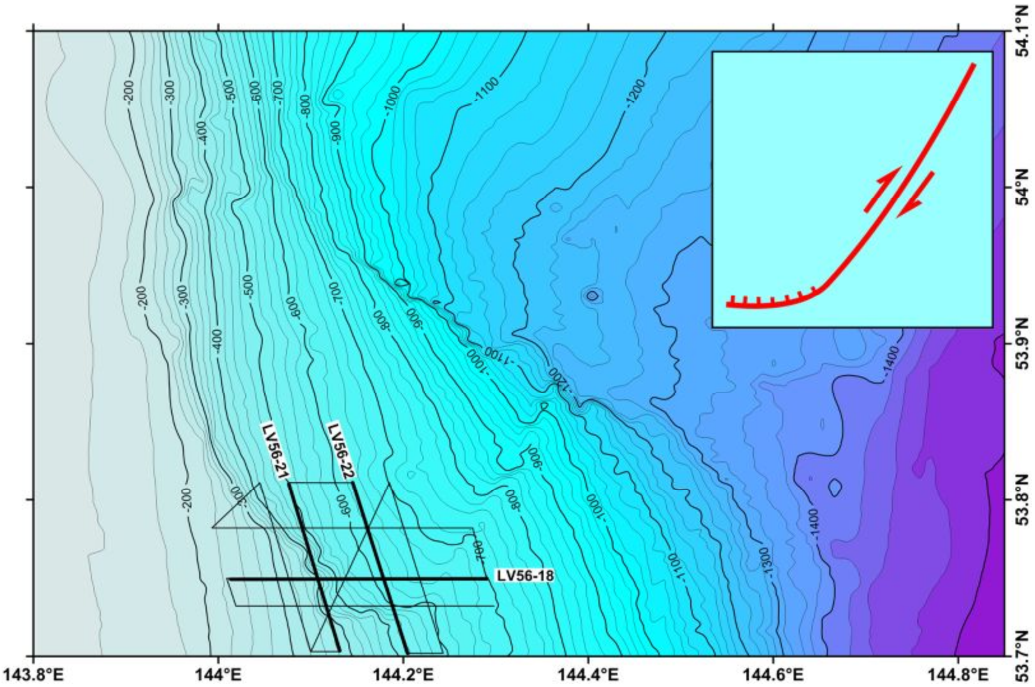


Fig. 2.1.7. Bathymetric map of the Lavrentyev Fault Zone. Black lines indicate location of bathymetric and seismic profiles of LV56 cruise. Contour line is 25 m. Inset shows suggested kinematics of the junction between NE and WE-striking faults.

Eight bathymetric and seismic profiles were run across LFZ during this cruise. All of them have crossed junction between upper scarp and scarp striking in NE-SW direction (Fig. 2.1.7). As a result of these investigations it was established that upper scarp actually strikes in NW-SE direction and its base is located at depth 400-500 m and its top lies at depth of 250-350 m. Its conjugation with NE-SW-striking scarp occurs through a canyon oriented in WE direction. The canyon has form of graben; one can see on profile LV56-21 (Fig. 2.1.8) that upper part of seismic section on the bottom of graben is identical with sections on its flanks. It is an evidence of young age of this structure.

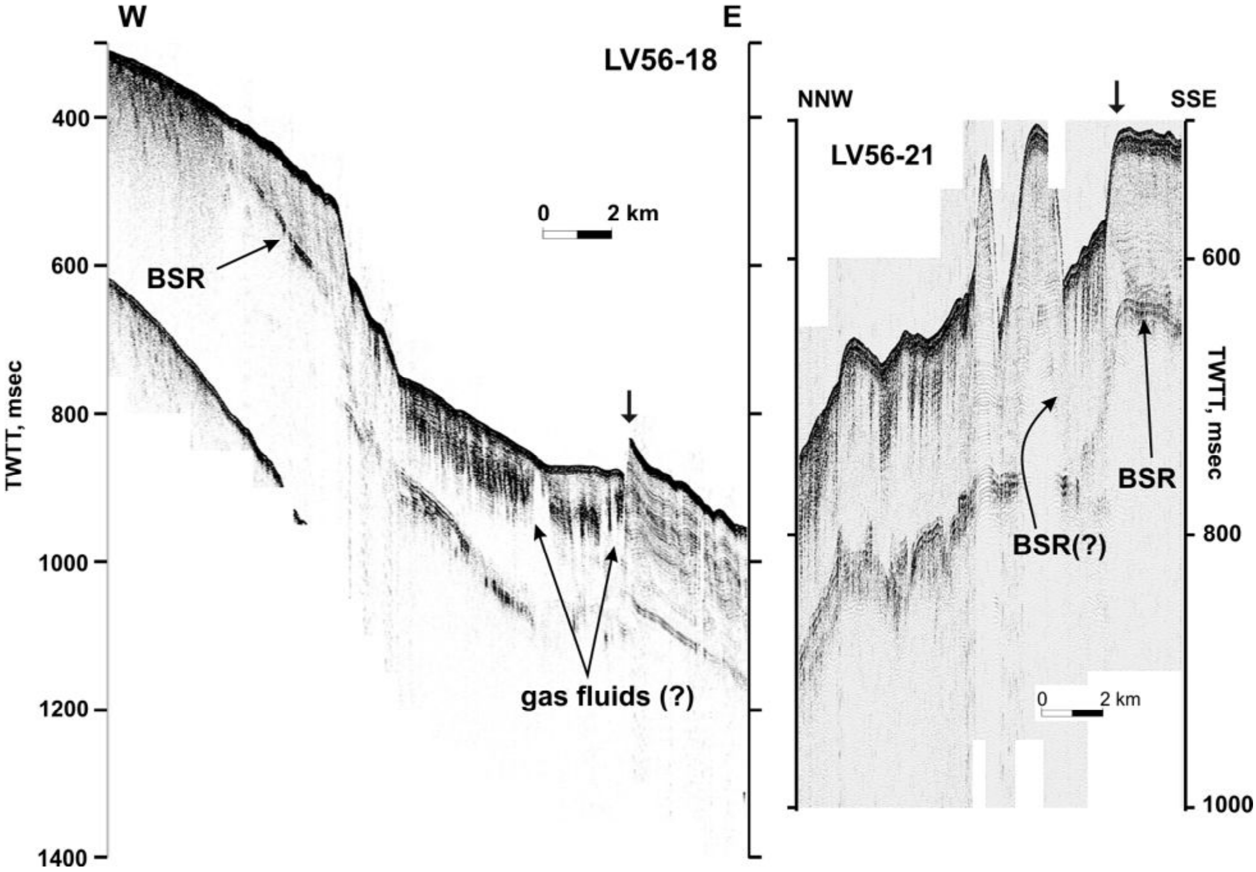


Fig. 2.1.8. Seismic profiles LV56-18 and LV56-21 showing structure of junction area between NW and NE-striking faults of LFZ. Arrows mark NE-striking fault on profile LV56-18 and WE-striking fault on profile LV56-21. See Fig. 2.1.7 for profiles location and text for additional explanation.

Southern flank of the graben has WE strike and gradually transforms into NE-striking scarp as it is seen on bathymetric map (see Fig. 2.1.8). Taking into account that the graben is restricted by normal faults and geometric relation described above we conclude that the NE-striking fault may be represented by dextral strike-slip (Fig. 2.1.8, inset). Additionally it is confirmed by difference in structure between wings of the NE-striking fault (Fig.2.1.8a); the last characteristic is typical for shears. The eastern wing is characterized by regular, parallel reflections. In the western part some reflectors occur only in the most upper cross-section; below the sedimentary section is transparent up to high amplitude reflector. The absence of the reflectors could be explained by two reasons, either occurrence of the mass wasting deposits or saturation of the sediments by gas.

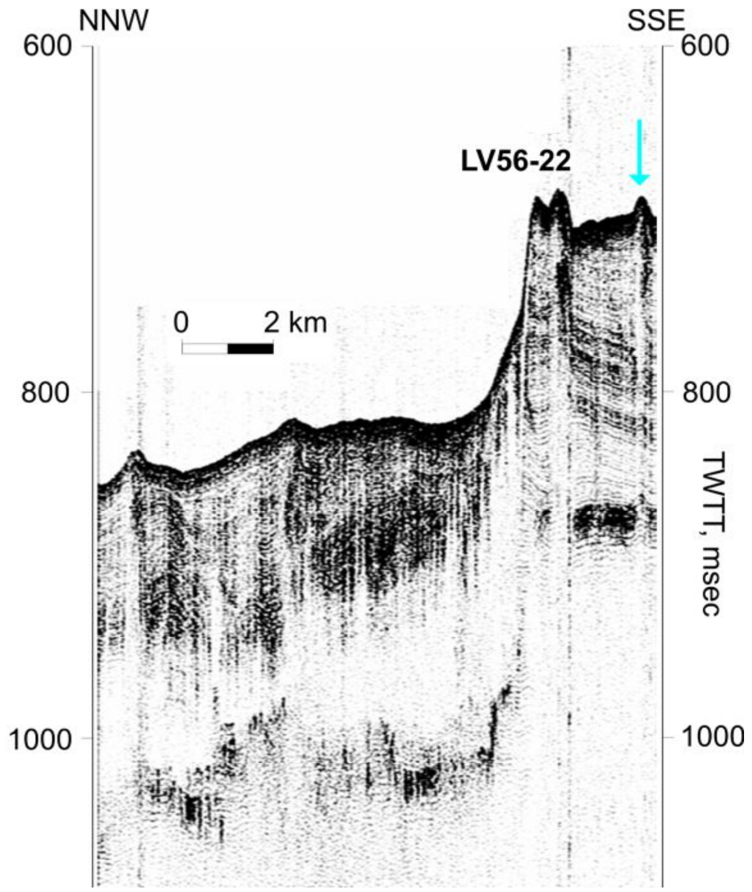


Fig. 2.1.9 Seismic profile LV56-22 showing gas chimney with gas flare marked by blue arrow. See location in Fig. 2.1.7.

Such indicators of gas hydrate presence as BSR, gas chimneys or gas flares were found on all profiles crossing Lavrentyev Fault Zone one of them is shown in Fig. 2.1.9 as example. Eight gas chimneys located in uplifted side of NE-SW-striking fault are distinguished. In some cases gas flares were registered above gas chimneys.

### *South of Lavrentyev Fault Zone*

Two seismic profiles were worked out southwardly from the Lavrentyev Fault Zone (see Fig. 2.1.2a). Profile LV56-26 runs along depth contours of 620-680 m on the slope from the Laverntyev Fault Zone (to the north) to the northern part of the SSS-surveyed area II (to the south). Previous studies show that the most intensive seepage activities occur around this water depth interval in the SSS-surveyed area 2 (Operation Report of SSGH 2009, 2010). Hydroacoustic (HA) profiles obtained during transit of SSGH 2006 cruise show an interesting feature that six gas flares (GF) seem to align with an interval of roughly 5 km. This profile was designed along the same track of HA profiles. This profile was expected to reveal the subbottom structures of the flares, i.e. gas chimneys (GC) and to fill geological information gap between LFZ and SSS-surveyed area 2.

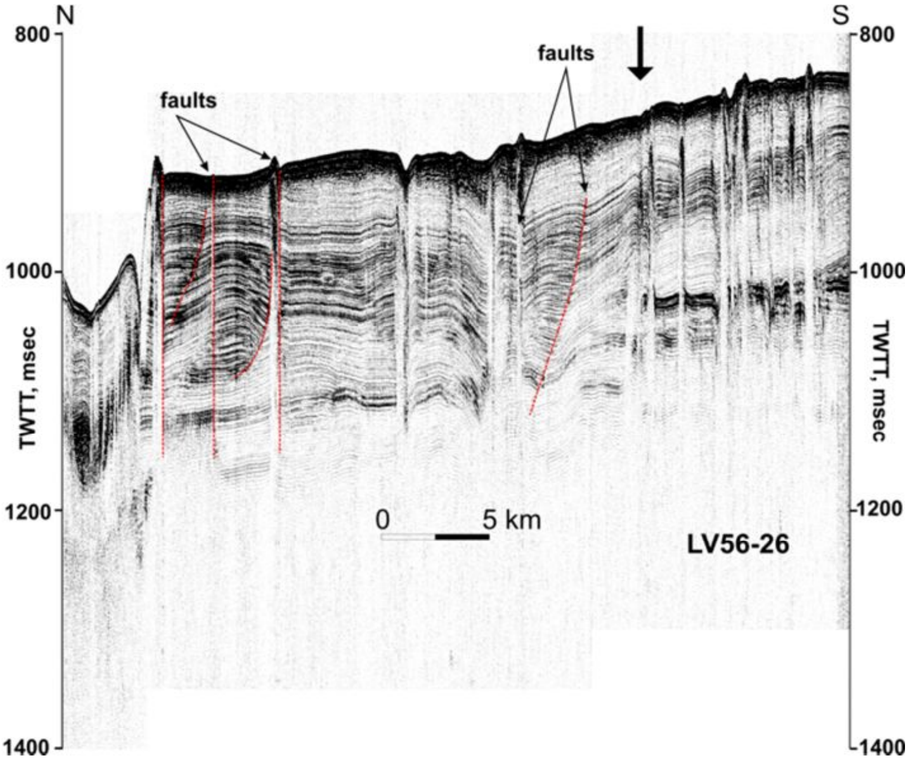


Fig. 2.1.10. Profile LV56-26 showing well-developed gas chimney structures. Arrow indicates a boundary of two areas showing different gas chimney occurrence pattern and seismic characteristics. See Fig. 2.1.2 a for location.

Profile LV56-26 shows a boundary at 53° 34.25' N where GC occurrence pattern and seismic reflection characteristics quietly change. To north of the boundary, five GCs occurred. Their sizes are relatively big up to 400 m in profile width. If one small chimney at 53° 38.1' N is excepted, their interval is roughly 5 km. The BSR is not distinct. In the southern area of the boundary, GCs are densely distributed with an interval of 1 to 2 km. Their diameters decrease up to roughly 100 m. High-reflective layers are revealed beneath a subbottom depth of about 170-180 m and also about 50 m-thick acoustic blanking zone is developed just above the layers. Top of the high-reflective layers is likely to correspond to the BSR. All GFs observed in HA profiles of SSGH 2006 show excellent correlation with GC structures on this profile, especially with mound structures. All GFs observed in HA profiles of SSGH 2006 show excellent correlation with GC structures on this profile, especially with mound structures. It is a surprise that the boundary at 53° 34.25' N completely corresponds to the northern boundary of SSS-surveyed area II designed with lack of information.

The second profile was conducted in the south of the area earlier investigated by side-scan sonar. As was shown before, morphology of this slope part is rather simple. Here the slope strikes in NNW10° with inclination about 1, 5° and has convex profile. Shelfbreak locates on depth 200-210 m, slope changes over the Deryugin Basin floor deeper 1500 m. According to structure of upper part of sedimentary cover this profile is similar to profiles obtained in this area in LV47 and LV50 cruises. Two slope areas are characterized by wavy shape of sea floor and these areas are located on upper slope between depth of 200-400m and on the Sakhalin continental rise between depth of 1000 and 1400m (Fig. 2.1.11). It is suggested that this relief forms represent by sedimentary waves (Wong et al., 2003).

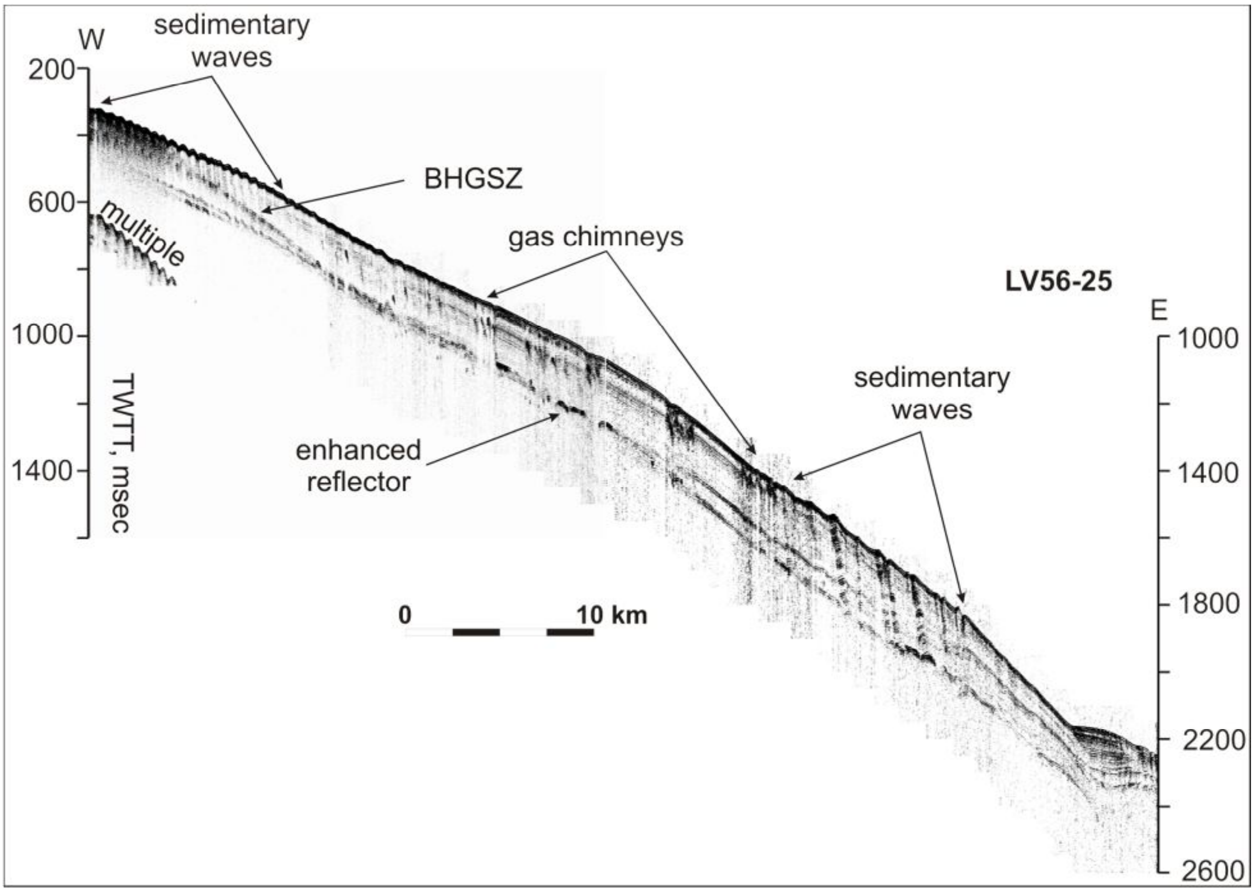


Fig. 2.1.11 Structure of the upper sedimentary cover in the southern part of study area 2. See Fig. 2.1.2a for profile location.

The high amplitude reflector (enhanced reflector) is the most remarkable feature existing on this profile. Below this reflector all other reflectors are almost absent. The high amplitude reflector locates on 200-220 ms below seafloor on eastern part of the profile. Upslope this reflector is parallel to the seafloor, but from depth of 800 ms below sea surface it is splitting on two reflectors. One of these reflectors starts to rise and almost touches the seafloor on depth of 400 ms (300 m). Other reflector is going parallel to the seafloor upslope.

This high amplitude reflector (enhanced) is disappeared in places where gas chimneys exist. This reflector is thought to be caused by strong acoustic impedance contrasts due to free gas accumulation below the BSR (Venneste et al., 2001) which is located above the enhanced reflector. The BSR touches at the seafloor at 300 m of water depth, indicating the top of GHSZ (gas hydrate stability zone) in the area is 300 m (Jin et al., 2011).

### 2.1.3.2. Study area 2

Study Area 2 locates on boundary between Southern and Central segments ( ~ 51°30'). It corresponds to trough oriented mainly in north-eastern direction and covered the depth interval of 800 - 1500 meters. On the small-scale map this structure looks like symmetric graben with steep southeastern and northwestern flanks. Bathymetric data, obtained in frame of KOMEX, CHAOS and SSGH-07 project suggest that relief of this structure is more complicated. Part of southeastern slope of this structure was mapped during the LV50 cruise and the very peculiar features represented by large NW-SE elongated depressions were found (Operation Report, 2011).

Early investigations suggest that study area 2 and Southern segment are characterized of abundance of conical depressions of different sizes. According to their morphology these depression were interpreted as gas originated features represented by pockmarks, giant pockmarks and gas calderas (Baranov et al., 2008). Gas flares were not detected in this area during survey and therefore we suggested that these gas structures are not active at present. Nevertheless existence of numerous gas structures (pockmarks) and total absence of any signs of their activity seemed to be an amazing fact.

Along with pockmarks other structures analogous to them by morphology and size but having different genesis are distinguished on the sea floor; they were called pockforms (Inglesias et al., 2010). It is supposed that pockforms may have sedimentary or structural nature. In the first case they originate due to irregular filling of channels and linear depressions by sediments. In the second case they are formed by post-sedimentation plastic deformations of sedimentary cover. Main difference between pockforms and pockmarks is the follows: in first case there are no any acoustic sign of gas occurrence and no cutting-out of sedimentary horizon on flanks of these structures (Judd, Hovland, 2007). This aspect was not investigated before due to leak of seismic data; that's why three seismic profiles were worked out in this area during the 56-th Cruise (see Fig. 2.1.3a) to study subbottom structure of these depressions.

Two seismic profiles crossed the trough in NS direction and one – in NE direction. In first turn existence of numerous disjunctive dislocations attracts one's attention on these profiles (Fig. 2.1.12). Disjunctive dislocations cross the whole visible part of sedimentary cover represented by well-stratified deposits. The faults are manifested in bottom relief in form of depressions and scarps; it points on their young age. Character of displacement of bottom surface and reflectors on some of the faults permit to suppose that they are normal faults. In some cases origination of normal faults is accompanied by forming of such structures as grabens or tension fractures (see Fig. 2.1.12). The faults manifested on bottom surface by V-like depressions prevail on the profiles; on them vertical dislocation of reflectors in sedimentary cover is not observed. Absence of vertical dislocations allows us to interpret such faults as strike-slips.

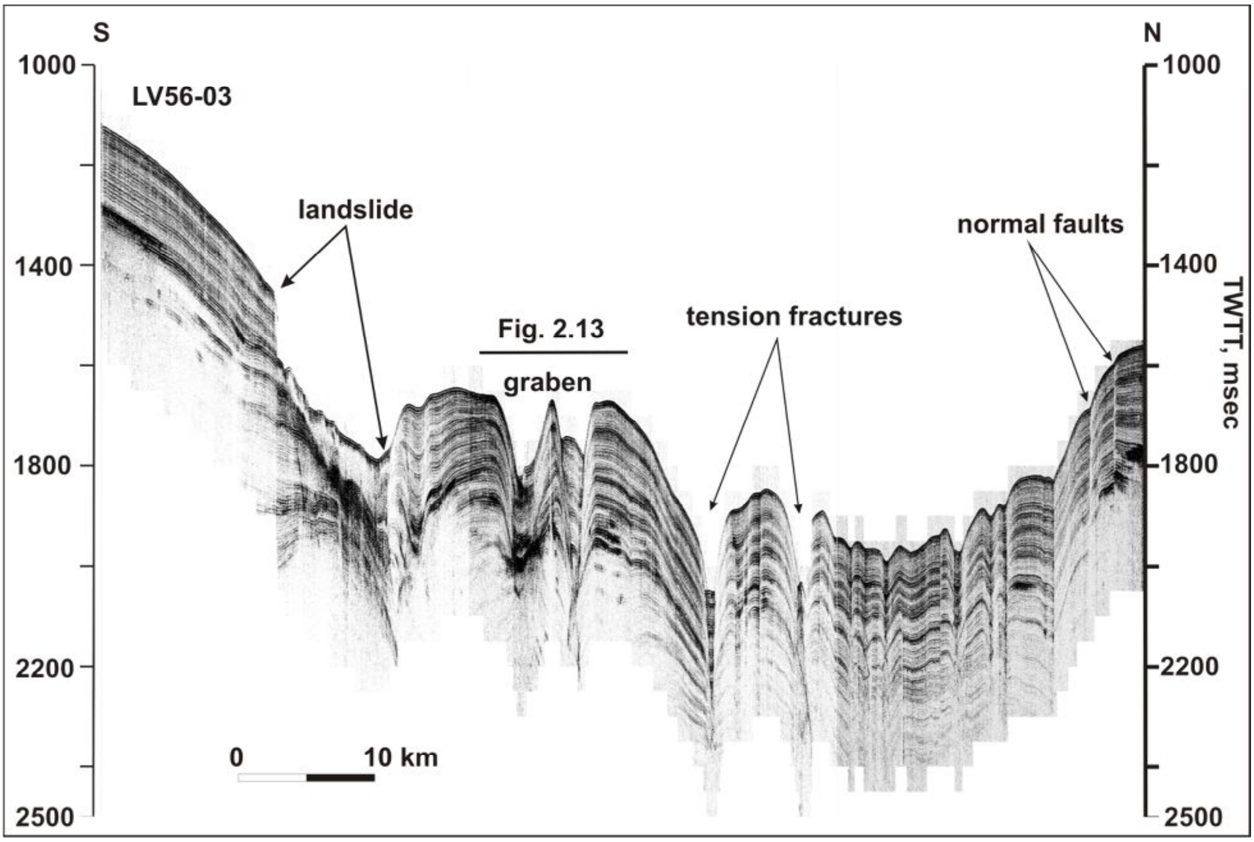


Fig. 2.1.12 Seismic profile LV56-03 across the boundary between Southern and Central segments. Numerous disjunctive dislocations have seen on this profile. See location in Fig. 2.1.3a.

Part of this profile cross area, which was mapped by multibeam echosounder in RV “Sonne” Cruise SO178 (Dullo et al., 2004). This area is located in depth interval 1020-1490 m on the south-eastern flank of the trough separating Southern and Central segments. In the western part of the station several isolated depressions are observed; they form chains oriented from north-west to south-east and slightly elongated in the same directions (Fig. 2.1.13). The depressions are separated by narrow height striking in north-western direction. Dimensions of the depressions reach 1-1.5 km and depths over see50 m.

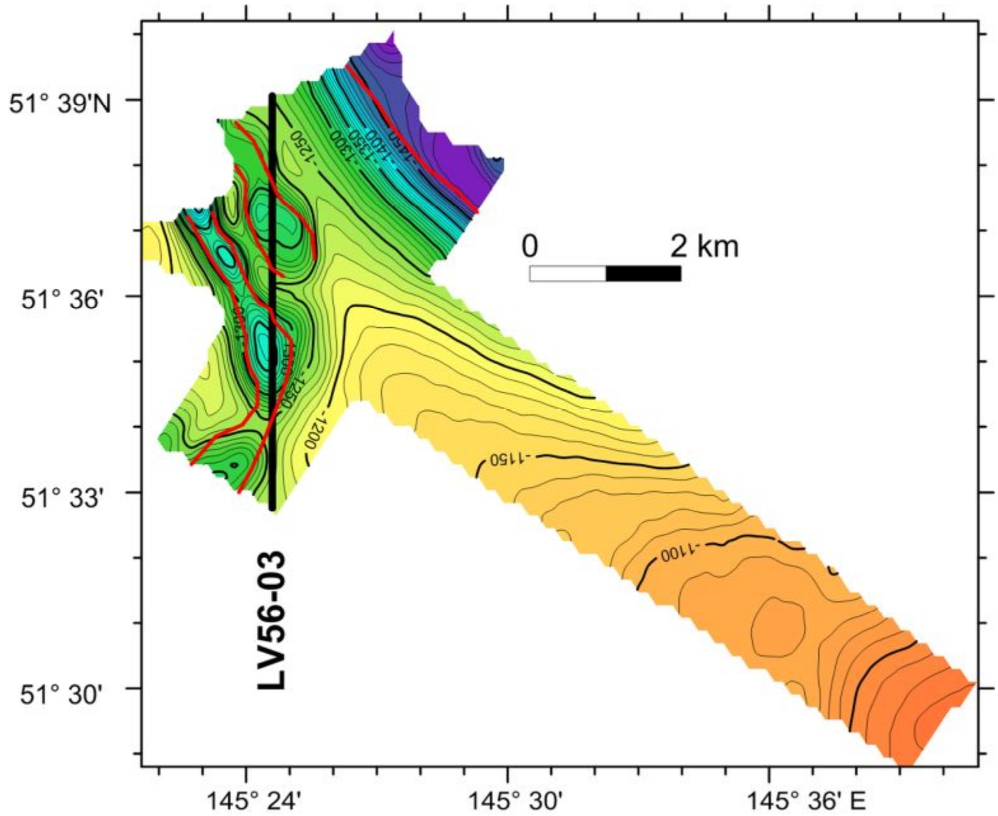


Fig. 2.1.13. Multibeam echosounder map of the Station 7 (cruise SO-178). Contour interval is 10 m. Black lines mark location of seismic profile, red lines indicate faults. Location of seismic profile crossing this map is shown in Fig.2.1.12.

Comparison of seismic profile LV56-03 (Fig. 2.1.12) and swath bathymetric map (Fig. 2.1.13) leads to conclusion that the depressions are not connected with gas seepage as it was supposed before (Baranov et al., 2008), but have tectonic nature, i.e. represent pockforms. It was mentioned above that the pockforms originate due to irregular filling of channels and linear depressions by sediments, due to post-sedimentation plastic deformations of sedimentary layer and due to slope failure. The depressions located in area 2 are obviously connected with structural dislocations along underlying fault system.

Along with faults another remarkable structure was found in frames of the investigated area. In southern part of profile LV56-03 one can see steep scarp with height over 150 m that cuts well-stratified sedimentary layer (see Fig. 2.1.12). Below the scarp there is a sedimentary body; its thickness increases downward the slope. Top of this sedimentary body has rough (hummocky) surface, reflectors either absent or have complicated structure. All these characteristics permit to conclude that this sedimentary body is a landslide.

Indicators of gas hydrate presence are absent on profile LV56-03, but they begin to appear in upper part of profile LV56-27 and on profile LV56-28 (Fig. 2.1.14). These indicators include BSR, enhanced reflector and gas chimneys. Nevertheless, gas flares were not registered in this area.

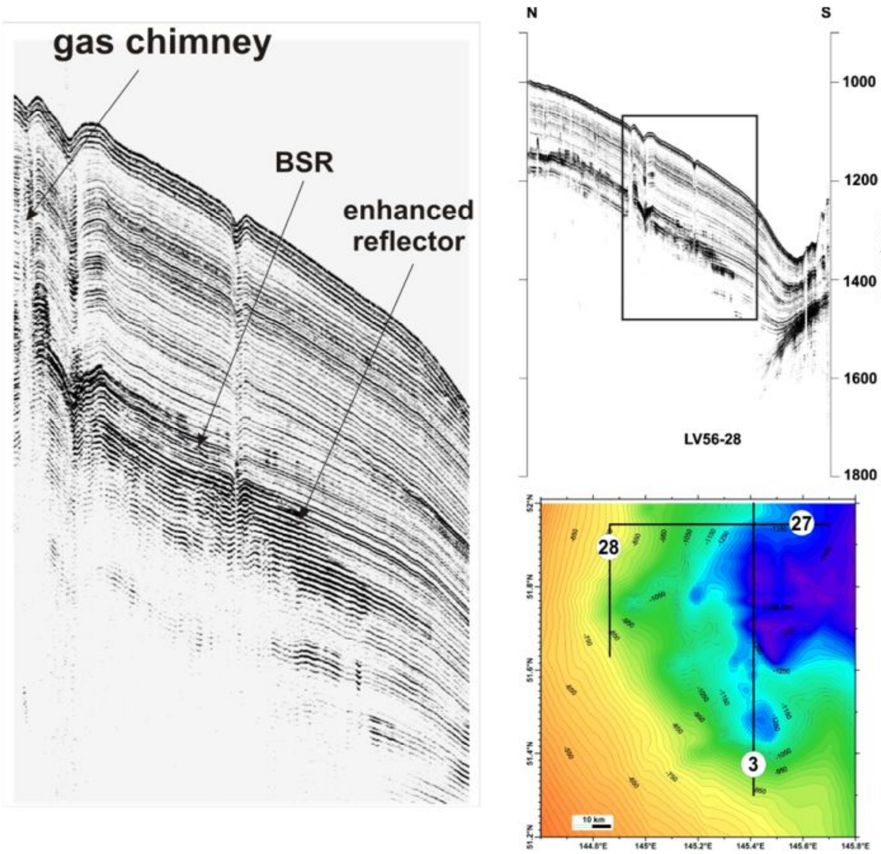


Fig. 2.1.14. BSR, enhanced reflector and gas chimneys start to appear in upper part of the slope inside Study area 2.

### 2.1.3.3. Study area 3

Study Area 3 locates the Sakhalin slope facing to the Kurile Basin. Our previous study has shown that the slope above depth of 1750 m consists of steep (scarp) and gentle (terrace) parts (Operation Report, 2011). The scarp is located in depth interval 250-1500 m and is cut by a number of canyons. Canyons strike in NS direction and have very steep slopes that indicate on their fault origin. The well-stratified seismofacies locates on the slope and canyon heads and its cross-section is visible up to 200 msec. In the lower canyons the amount of reflector starts to decrease and and well-stratified facies transforms to reflector poor facies. Reflector poor facies spreads over the terrace starting from depth of 1500 m and probably represents the mass wasting material.

In 56-th Cruise eastern and western slopes of the Terpeniya Ridge, Kurile Basin slope and continental slope adjacent to Aniva Peninsula were studied within study area 3 (see Fig. 2.1.3b). Terpeniya Ridge is underwater continuation of Terpeniya Peninsula and represents a block with steep eastern slope and gentler western slope. Reflectors are absent, very weak or presented by very thin horizon in the upper part of seismic sections on the eastern slope (Fig. 2.1.15a). Absents of well-manifested reflecting boundaries is possibly conditioned by active erosion of the eastern slope accompanied by outcropping of more ancient sedimentary rocks; the last play role of the acoustic basement for used seismic equipment.

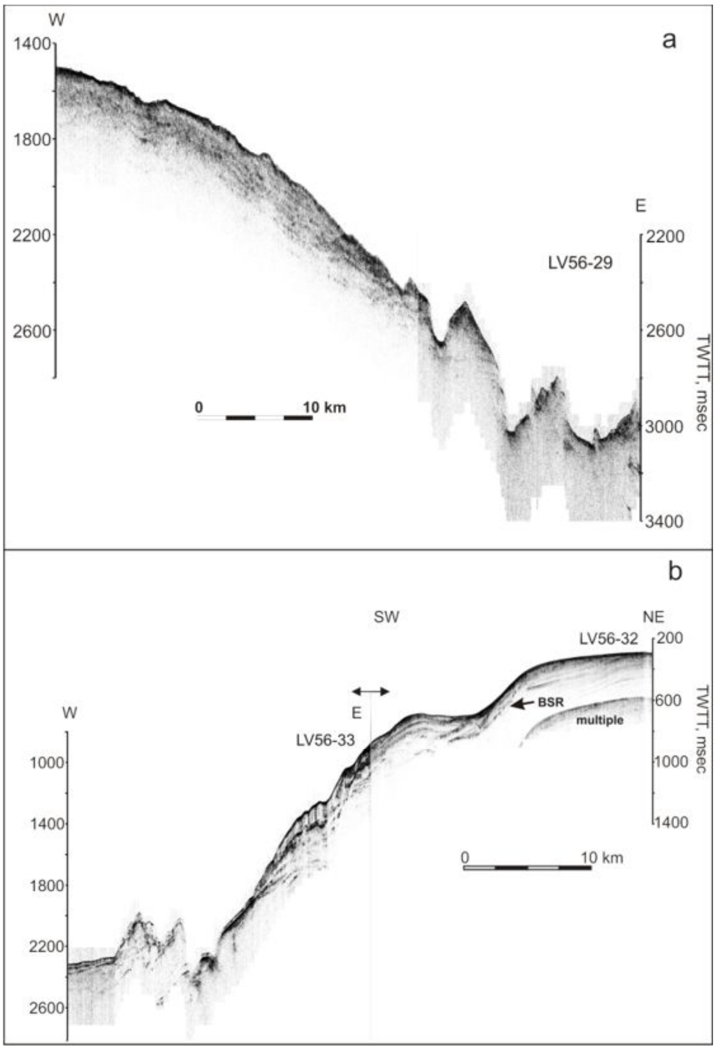


Fig. 2.1.15. Seismic profiles showing upper sediment structure for eastern (a) and western (b) slopes of the Terpeniya Ridge. See Fig. 2.1.3 b for profiles location.

Basing on dredging data (Tsoi, Shastina, 2000; Terekhov et al., 2008) it was established that the lower part of the sedimentary section is composed by mudstones containing complexes of Paleocene - Early Eocene and Early Oligocene radiolarians. Overlying tuff-diatomite layer is composed by strata of Late Oligocene –Early Miocene, and of Early Miocene - Middle Miocene age. Cenozoic sediments overlap with unconformity Maastrichtian – Danian volcanic-clastic and volcanic-sedimentary rocks of the basement (Terekhov et al., 2010).

Western slope of the Terpeniya Ridge is less steep and consists of several steps (Fig.2.1.15b). Reflectors within this slope are traced down to depth of 240 msec. On the top of the ridge located at depth 225 m sedimentary horizons are inclined in western direction and are cut by bottom surface in the east. It may justify that the top of the ridge suffered wave erosion before its subsidence. In the upper part of the slope BSR is distinguished; it approaches bottom surface at depth of about 300 m. Lens-like sedimentary body most likely formed due to contourite streams is observed on the step in middle part of the slope. Downward along the slope visible thicknesses of the sedimentary cover gradually decrease and sediments totally disappear at depth of 1580 m. In the western part of the profile the slope flattens out forming a terrace. The terrace is separated from the slope by small rise and trough with height/depth about 250 m. In the upper part of the section chaotic reflectors are observed on the rise; the reflectors are absent in the trough. Upper part of the rise with chaotic reflectors is obviously a landslide and the trough is a fault.

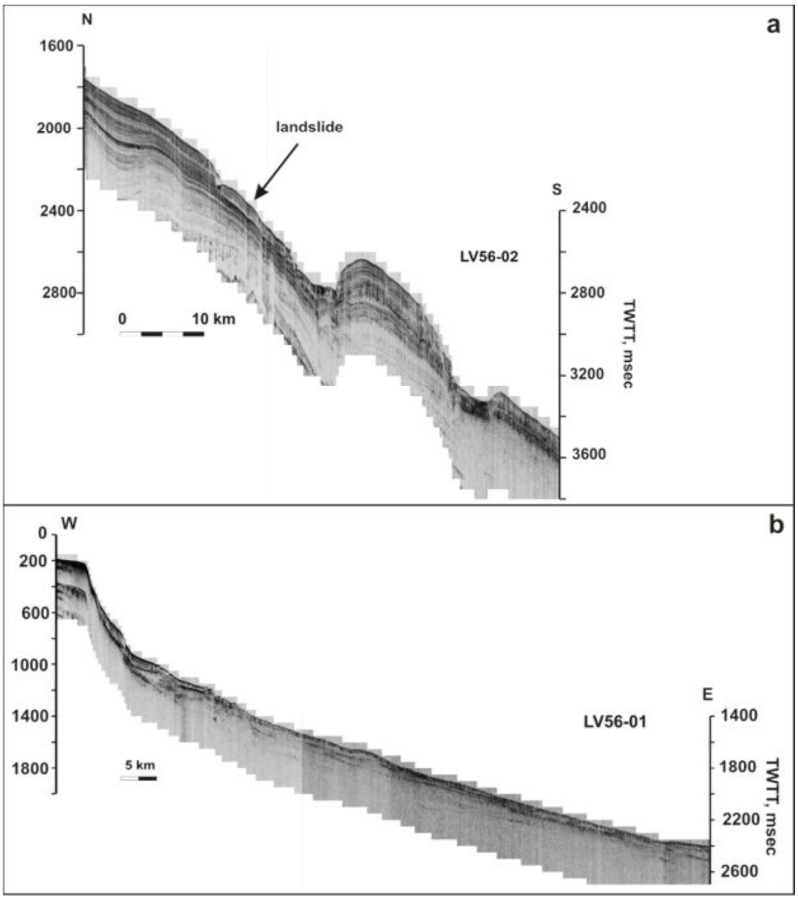


Fig. 2.1.16. Seismic profiles showing upper sediment structure for Kurile slope (a) and Aniva part of slope (b). See Fig. 2.1.3 b for profiles location.

Kurile slope is characterized by fine-stratified sedimentary cover with visible thickness up to 450 m (Fig. 2.1.16a). Two sedimentary units may be distinguished in the cover. The upper one contains distinct reflectors and has thickness from 400 m in upper part of the slope to 150 m in its lower part. The lower unit is also characterized by existence of numerous but weaker reflectors. Upper sedimentary horizons of this unit are cut by bottom surface on the rise in the central part of the slope; it may be conditioned by erosion or sliding processes. One of the slides (its location was detected on base of multibeam survey in RV "Sonne" Cruise SO178 (Dullo et al., 2004)) is distinctly seen on the profile (see Fig.2.1.16a).

BSR was distinguished by investigations in 50-th Cruise of RV "Akademik Lavrentyev" in EW-striking part of the slope within study area 3 (Operation Report, 2011), and during 56-th Cruise the BSR was found on the western slope of the Terpeniya Ridge; it may point on gas hydrates presence in sediments. But more reliable indicators of shallow gas hydrates presence (gas flares, gas chimneys and BSR) were observed along profile crossing the NS-striking part (Aniva) of slope (Fig. 2.1.16b).

One can see on this profile that upper part of the slope is rather steep and after contour line 750 m it begins to flatten out gradually (se Fig.2.1.16a). Strong reflector is detected in the upper part of the slope; below it the reflections are absent. Strong reflector touches the bottom at depth 300 m and dips downward the slope reduplicating relief surface; it permits to conclude that it is BSR. Two sedimentary units are distinguished above BSR. The first of them is well-stratified and has thickness 100 m. The second one appears below relief scarp which obviously is a fault. This unit is separated from the upper unit also by strong reflector; reflections in it are blanked or there are turbidity reflectors. Upper unit flattens out downward the slope and below 900 m top of the lower unit comes out on the surface forming hummocky relief which is traced down to contour line 1140 m. Below 1140 m reflecting horizons are rather elongated but few in number; according to Wong et al., 2003 here are reflector poor facies traced up to 170 m below bottom surface. Seismic characteristics and lower sedimentary unit's top relief permit to suppose that it is composed by mass wasting material.

Gas chimney with gas flare in water column was found on this profile (Fig. 2.1.17). It is located above strong reflector separating upper and lower sedimentary units and according to its seismic characteristics is similar to gas chimneys distinguished in northern segment (Jin et al., 2011); it is a diffuse, dark-colored (enhanced reflection) chimney (ER). Similar seismic parameters of gas chimneys are obviously conditioned by analogous conditions of their forming inside landslide bodies.

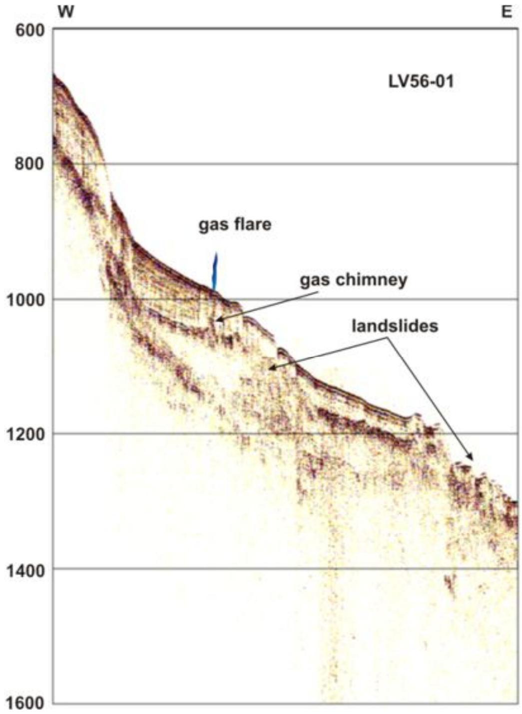


Fig. 2.1.17. Part of profile LV56-01 showing structure of the sedimentary cover across the gas flare recorded during LV56 cruise.

## Conclusions

1. Two seismic profiles obtained in the most northern part of the study area 1 do not show existence of structures like gas chimneys. This fact along with the fact that only one gas flare was registered here may justify that gas seepage here is less active and prospective for gas hydrates as compared with the areas to the south from the canyon.

2. A number of big gas chimneys were found in area of Lavrentyev Fault Zone. Typical relief forms represented by mounds correspond to gas chimneys on the sea bottom and gas flares appear on some of them. Therefore area of Lavrentyev Fault Zone represents first-turn interest for gas hydrates sampling.

3. Comparison of seismic profiles and swath bathymetric map for study area 2 leads to conclusion that the conical depressions are not connected with gas seepage as it was supposed before (Baranov et al., 2008), but have tectonic nature, i.e. represent pockforms. It was mentioned above that the pockforms originate due to irregular filling of channels and linear depressions by sediments, due to post-sedimentation plastic deformations of sedimentary layer and due to slope failure. The depressions located in area 2 are obviously connected with structural dislocations along underlying fault system.

Anyway evidence of gas hydrates potential start to appear upward slope. This evidence includes BSR, enhanced reflector and gas chimneys. Nevertheless, gas flares were not registered in this area. Therefore to clarify this question we need investigate this area in more details.

4. Several gas flares were recorded in N-S-striking part of the Kurile segment of the slope at depths over 300 m. BSR, gas chimneys, topographic features are also observed there. These facts may give evidence of shallow gas hydrates formation.

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## 2.2. Hydroacoustic Investigation

*A. S. Salomatin, B.Y. Li*

The main goal of hydroacoustic survey was the search and investigation of underwater gas seepage acoustic manifestations. For this purpose, collection of information about acoustic back scattering level was carried out simultaneously using frequencies of 12 kHz, 20 kHz and 135 kHz in the water column and from the seabed.

The data obtained can be used also for:

- evaluation of the gas seepages intensity;
- accurate determination of the depth, estimation of the reflection coefficient and other seabed characteristics;
- registration of the frontal zones, internal waves and other oceanological processes;
- study of a spatial distribution of fish, zooplankton, and acoustic evaluation of their biomass.

The hydroacoustic observations were carried out using a hydroacoustic complex created on the basis of the upgraded ship's echo sounders Sargan-EM and ELAC, sonars Sargan-GM (Fig. 2.2.1) and multichannel digital registration system (Fig. 2.2.2). The hydroacoustic complex provided a possibility of simultaneous registration of sonar echoes on four independent channels with frequencies of 12 kHz, 20 kHz and 135 kHz. At a time with acoustic measurements, accurate vessel's coordinates are estimated with the help of global positioning system (GPS). Block-scheme of the complex is represented on the Fig. 2.2.3, its basic parameters are listed in the Table 2.2.1.

Fig. 2.2.1. Echo sounder Sargan-EM and sonars Sargan-GM

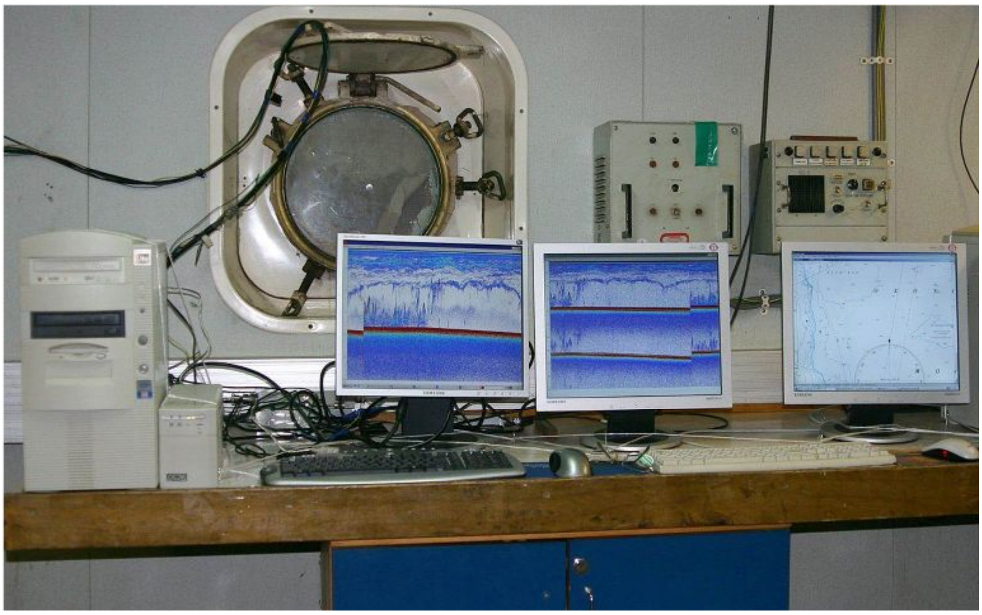

Fig. 2.2.2. Multichannel digital registration system

Table 2.2.1. Main parameters of acoustic equipment

| Device | ELAC | Sargan-EM | Sargan-GM | |
|---|---|---|---|---|
| Operating frequency, kHz | 12 | 19.7 | 19.7 | 135 |
| Beamwidth, grad | 12 | 10 | 14 | 4 |
| Output power, W | 2000 | 6000 | 2500 | 2000 |
| Impulse length, ms | 0.8; 3; 10 | 0.5; 1; 3; 10 | 1; 3; 10; 30 | 0.3;1; 3 |

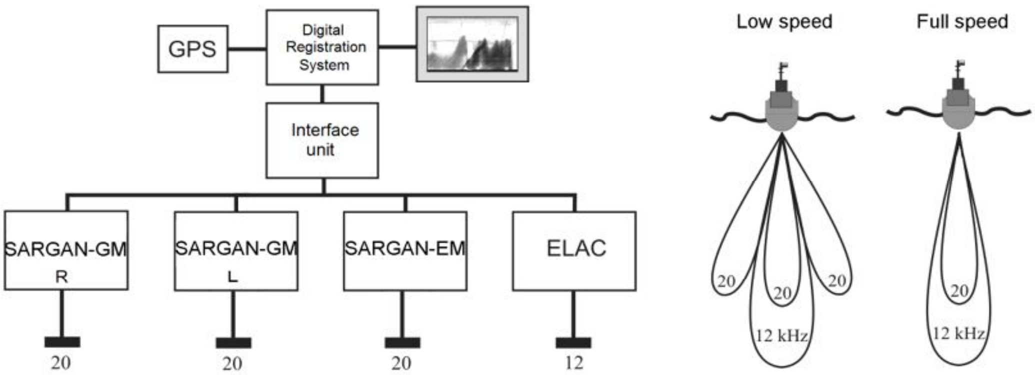


Fig. 2.2.3. The hydroacoustic complex block-diagram.

Record of acoustic back-scattering signals was made in two basic regimes:

1. *The background observations* (configuration “full speed”) were conducted continuously within all studied area on a full speed of a vessel (9-12 knots), thus the echo sounders Sargan-EM and ELAC (two channels of frequency - 12 and 20 kHz, sounding executed in a vertical direction) were used.
2. *The acoustic survey* (configuration “low speed”) was conducted in given areas on a mean speed of a vessel (3-6 knots). The echo sounders Sargan-EM and ELAC of frequency 12 and 20 kHz (two rays in a vertical direction) and a sonar Sargan-GM of frequency 20 kHz or 135 kHz (two rays, an angle of $30^o$ from a vertical direction in a side from a vessel movement) were used. Application of such regime has allowed to increase approximately three times viewed square during search of submarine gas sources and to estimate the position of these sources relative to the vessel.

*The multichannel digital registration system* is designed for the collection, initial handling, accumulation and visualization of the hydroacoustic information from four channels simultaneously and it includes:

- the interface unit;
- two sound cards Creative Labs;
- personal computer (Pentium-II and higher);
- operation system Win32 type;
- “Sonic” software for input, handling, storing and visualization of echo-signals.

Echo-signals are converted to digital form with the help of four 16-bit analog-to-digital converters of sound cards; their synchronous detection and low frequency filtration are carried out further. The parameters of echo-signal registration (range of registered depths, mean sound speed etc.) are set by the program (see Fig. 2.2.4) or with the help of initializing file.

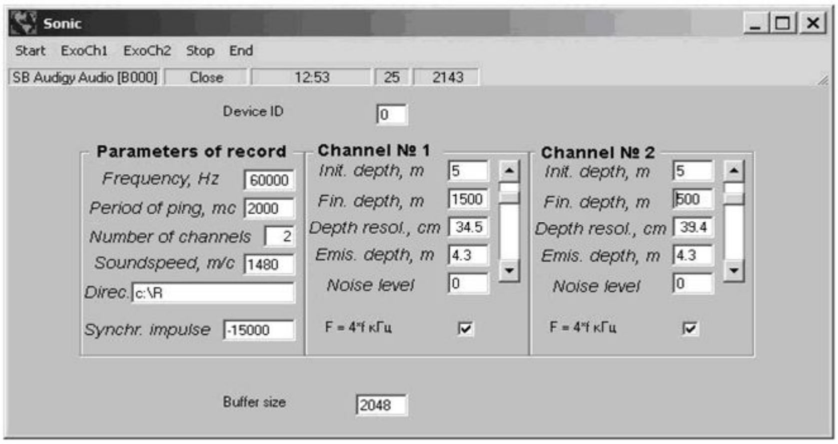


Fig. 2.2.4. An example of “Sonic” initial dialog

The digitized echo-signals are recorded as data files on a hard disk of the computer. The dynamic range of a system exceeds 90 dB.

Record format of echo-signals is following: first 8 bytes – date and time of echo sounder ping (type of variable – *date* of Visual Basic 6 system programming), further the values of echo-signals of given ping follow in the order of depth increase, with which they come. Each counting of echo-signal takes 2 bytes (type of variable - *integer*). Number of counting (*N)* is equal to ratio of registered depth range to depth resolution, and therefore the record of one ping takes *8+2N* bytes. The name of a data file is determined by both a channel number of a sound card and time of the first echo-signal in this file (in hours and minutes). For example, if the first echo-signal was sent by June 1, 2010 at 2 hours 25 minutes, the data file is recorded under name *0225.1dt or 0225.2dt*, depending on channel numbers in a folder *Data\1Jun10* or *Data1\1Jun10* depending on numbers of a sound card. Additionally, configuration file *0225.1cf* or *0225.2cf* is recorded in the same folders as initializing file (INI-file) with the necessary information about parameters of echo-signal registration (see Table 2.2.2).

Table 2.2.2 An example of configuration's file

| | |
|---|---|
| [Common] | Freq = 19700 |
| date=6/6/2010 | Working frequency |
| time=2:07:36 | hAnnt = 4.3 |
| name Vessel – Academic M.A. Lavrentyev | [SoundCard] |
| region = Okhotsk Sea | Device ID = 0 |
| nCh = 1 | Freq = 60000 |
| soundSpeed = 1480 | uMax = 1 |
| Sound speed in water, m/sec | [ParReg] |
| Period=2000 | hBegin = 5 |
| Period of ping, m/c | hEnd = 1500 |
| nF=1200 | h = 29.6 |
| Number of pings in the file | N = 5051 |
| Dir=e:\Lavr50\20-R | [Ver] |
| dateEnd=2:07:36 | Ver = 1.0.0.1 |
| [Echosounder] | |

The visualization of echoes in real time is carried out using two standard colour monitors. Each channel is represented on the two multi-coloured echograms with independent range of depths and with independent colour palette. The software provides synchronous detection, filtration, registration and visualization of an echo signal in the required range of depths.

The digital registration system has two synchronization modes - internal and external. In a mode of internal synchronization all acoustic devices are managed by the digital registration system. This mode is preferential, because it allows vary a frequency of ping. At an external synchronization mode one of echo sounders is master and it manages other devices and digital registration system. The external synchronization mode is enforced and it is applied in cases, when one of echo sounders does not support external trigger. In current cruise the mode of external synchronization was used.

## Preliminary results

About 118 crossings of 96 gas flares (GF) were carried out during the vessel movement; about 30 of them were found for the first time. Total time of acoustic survey amounted to 290 hours. Total length of acoustic survey amounted to 2300 miles. GF were registered at different depths of the seabed - from 105 up to 1480 meters, but the largest number of GF was registered in the range of depths of 600-900 meters.

Figure 5 shows spatial position the registered GF and Table 3 gives the coordinates of GF, course and speed of the vessel and depth of the seabed.

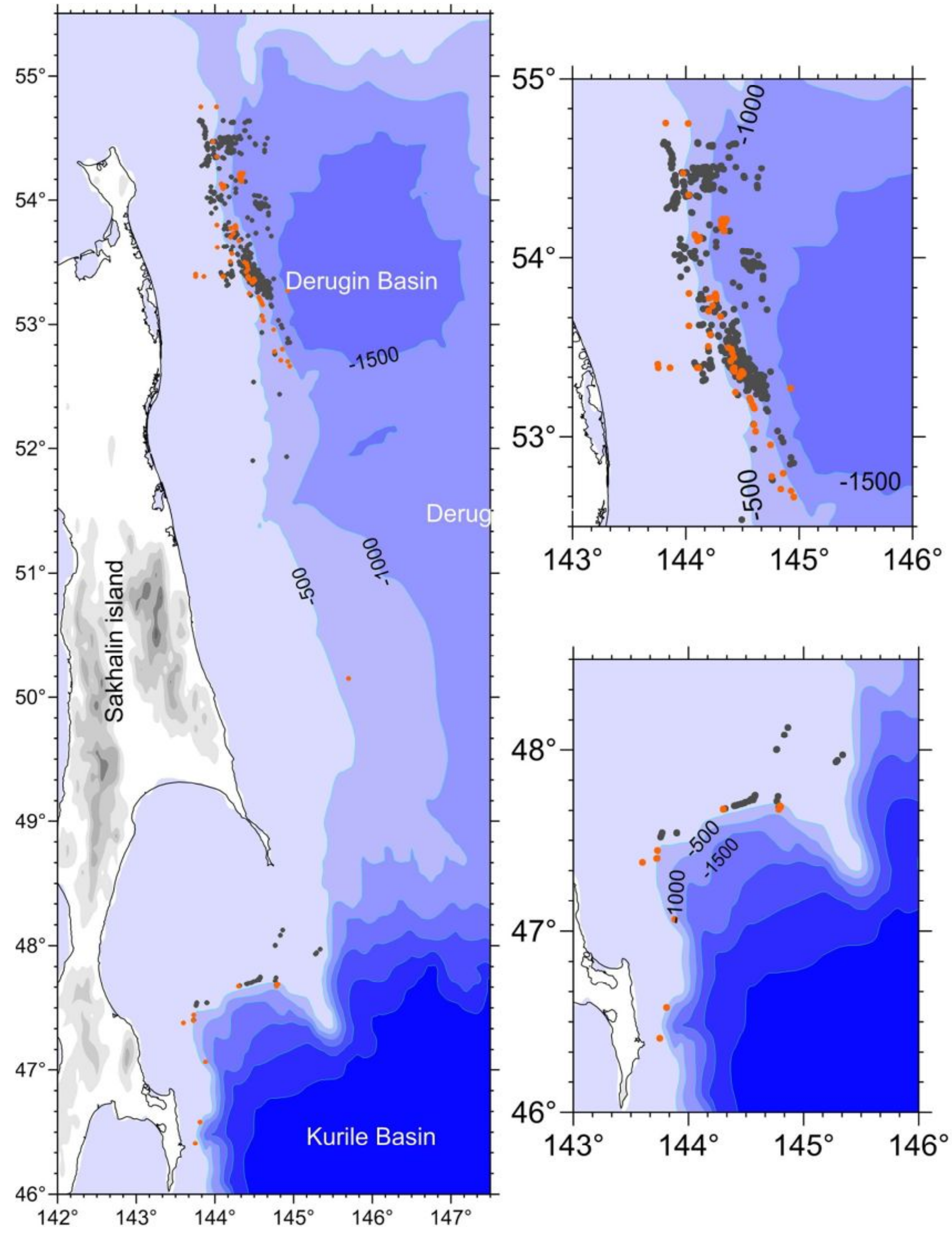


Fig. 2.2.5. The scheme of GF registered in 2008, 2009, 2010 and 2011 years, cruise 44, cruise 47, cruise 50 - dark blue circles, cruise 56- red circles.

For the first time observation of GF in the new area with coordinates 50° 8,969' N145° 41,959' E was made into the pockmark. Examples echograms obtained over pockmark are shown in Fig. 2.2.6.

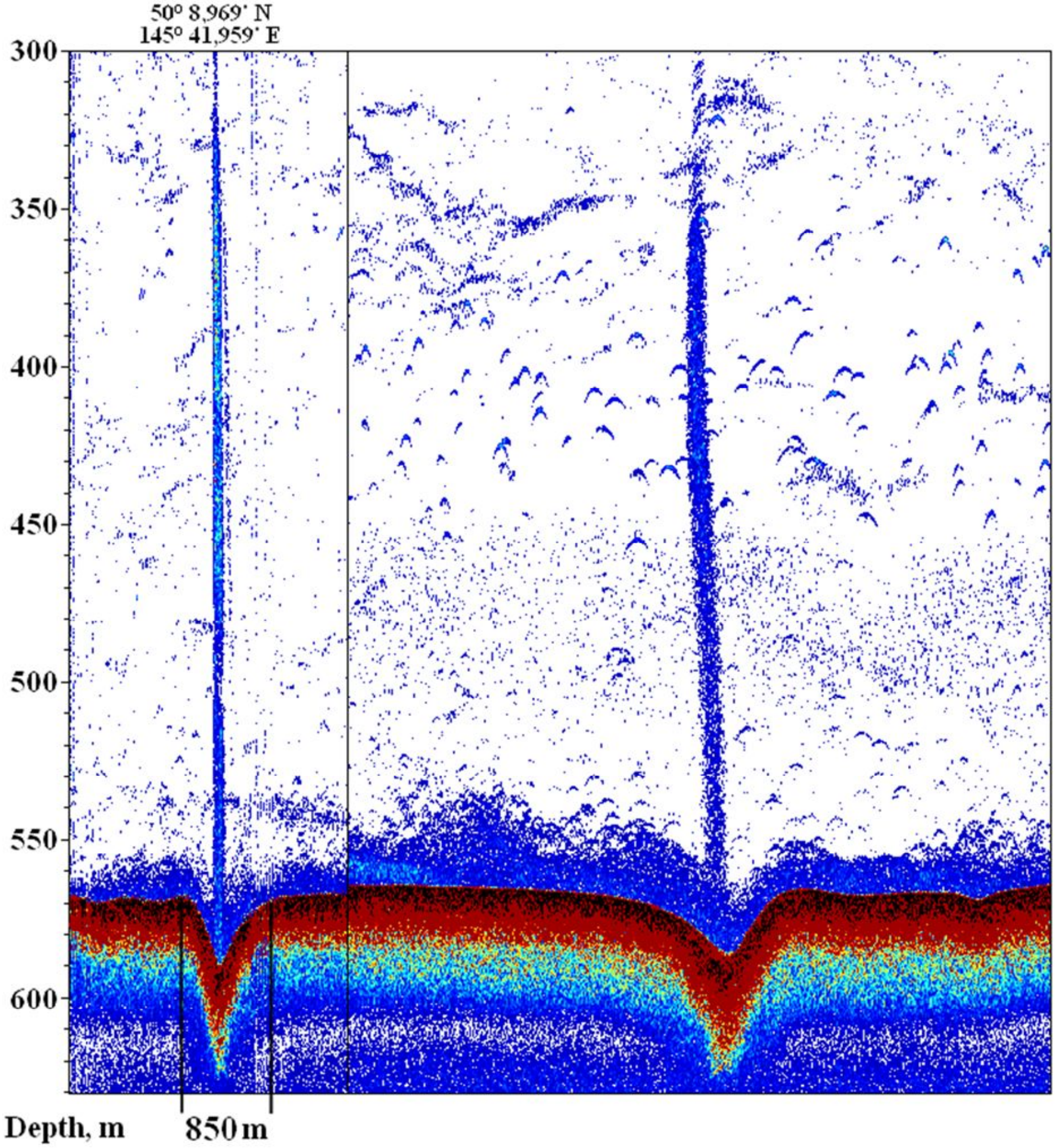


Fig. 2.2.6. The echogram GF obtained over two crossings of pockmark.

The deepest F61a and the shallowest SF72 GF were registered during the cruise.

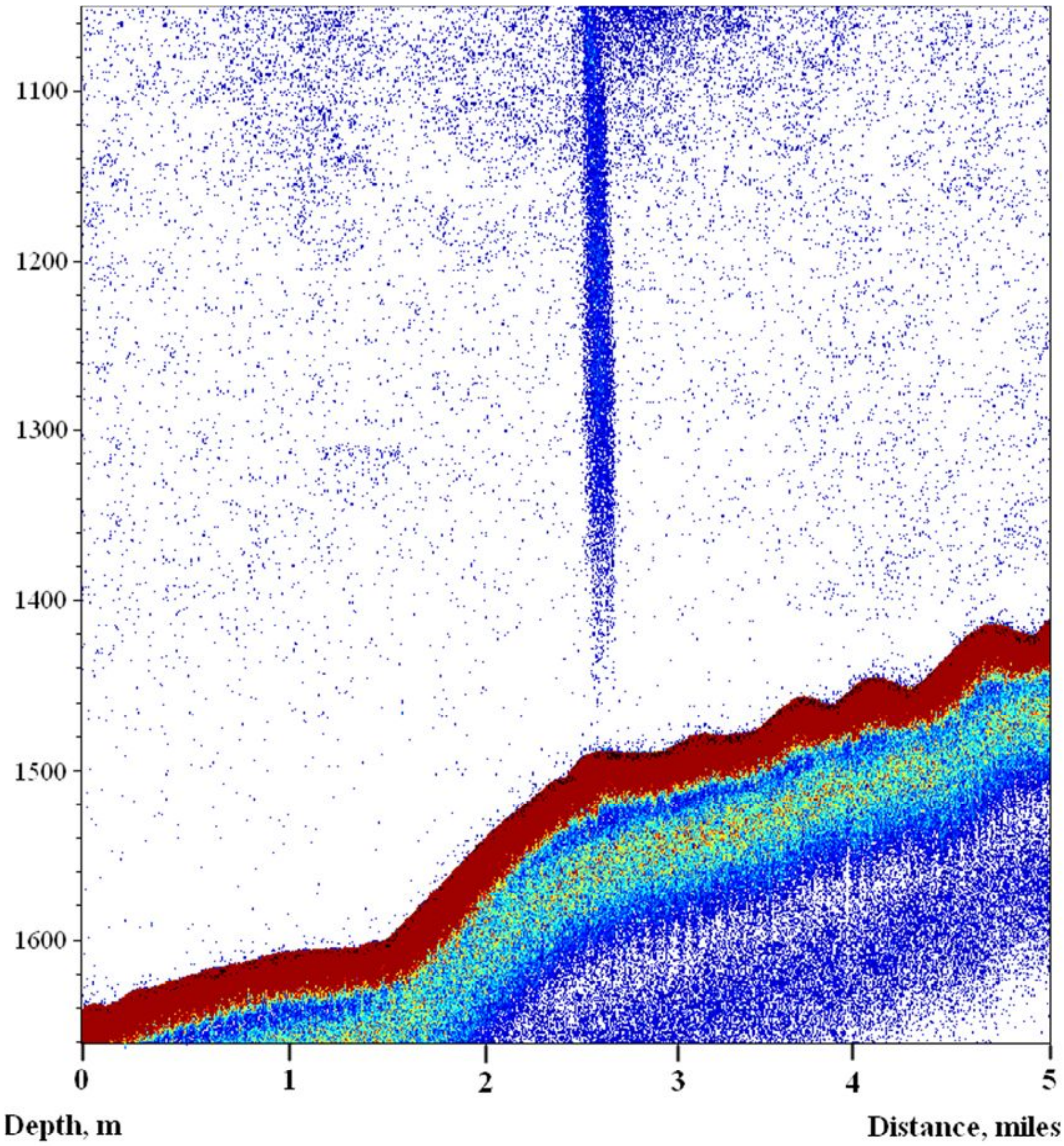


Fig. 2.2.7. The echogram of deepest GF

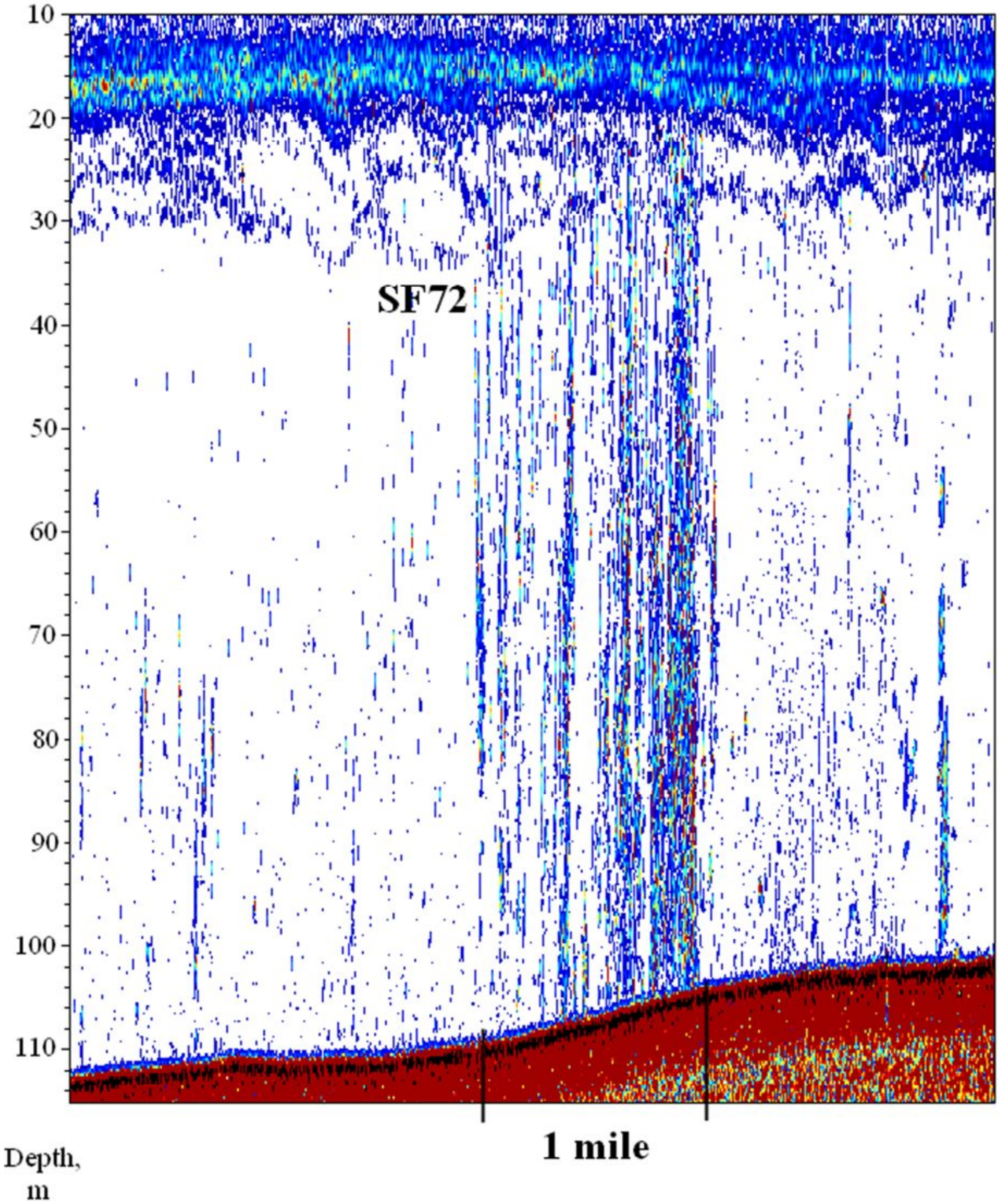


Fig. 2.2.8. The echogram of shallowest GF

Frontal zones, internal waves and other oceanological processes registered during the cruise.

Table 2.2.3 List of hydroacoustic “flare”-type anomalies

| Name | Date | UTC Time | Latitude | Longitude | Speed | Course | Depth, m |
|---|---|---|---|---|---|---|---|
| SF1 | 13/08/2011 | 10:12:22 | 47°22,740' N | 143°36,065' E | 10,3 Kts | 0,0° | 143.0 |
| F2 | 13/08/2011 | 11:28:12 | 47°23,992' N | 143°43,618' E | 05,7 Kts | 93,0° | 736.1 |
| F3 | 14/08/2011 | 16:22:02 | 50°08,969' N | 145°41,959' E | 10,4 Kts | 350,8° | 587.0 |
| F4 | 15/08/2011 | 11:03:45 | 52°39,790' N | 144°57,085' E | 11,7 Kts | 337,9° | 923.9 |
| F5 | 15/08/2011 | 11:16:20 | 52°41,930' N | 144°55,604' E | 11,1 Kts | 337,0° | 929.5 |
| F6 | 15/08/2011 | 11:51:01 | 52°47,853' N | 144°51,465' E | 11,1 Kts | 338,2° | 940.8 |
| F7 | 15/08/2011 | 12:48:14 | 52°57,321' N | 144°44,817' E | 10,7 Kts | 336,1° | 925.3 |
| F8 | 15/08/2011 | 14:02:02 | 53°09,371' N | 144°36,321' E | 10,8 Kts | 337,2° | 805.7 |
| F9 | 15/08/2011 | 14:06:35 | 53°10,120' N | 144°35,786' E | 10,9 Kts | 335,6° | 802.1 |
| f10 | 15/08/2011 | 14:09:59 | 53°10,681' N | 144°35,394' E | 10,7 Kts | 338,6° | 797.3 |
| F11 | 15/08/2011 | 14:18:40 | 53°12,096' N | 144°34,411' E | 10,7 Kts | 338,7° | 783.0 |
| F12 | 15/08/2011 | 14:19:48 | 53°12,283' N | 144°34,280' E | 11,3 Kts | 336,7° | 780.6 |
| f13 | 15/08/2011 | 14:24:24 | 53°13,050' N | 144°33,765' E | 11,2 Kts | 339,4° | 773.4 |
| F14a | 15/08/2011 | 15:08:40 | 53°20,297' N | 144°28,774' E | 10,7 Kts | 340,6° | 692.0 |
| F14 | 15/08/2011 | 15:09:48 | 53°20,488' N | 144°28,660' E | 10,8 Kts | 340,6° | 687.2 |
| F15 | 15/08/2011 | 17:01:44 | 53°22,681' N | 144°25,472' E | 05,2 Kts | 272,8° | 625.2 |
| F16 | 15/08/2011 | 20:07:55 | 53°23,108' N | 144°25,556' E | 04,7 Kts | 177,1° | 623.2 |
| F17 | 15/08/2011 | 20:13:36 | 53°22,673' N | 144°25,547' E | 05,3 Kts | 178,5° | 628.1 |
| F18 | 15/08/2011 | 21:41:54 | 53°22,857' N | 144°25,108' E | 01,3 Kts | 86,0° | 614.4 |
| F18-1 | 15/08/2011 | 21:56:21 | 53°22,859' N | 144°25,112' E | 00,0 Kts | 86,0° | 614.4 |
| F19 | 15/08/2011 | 22:50:28 | 53°23,126' N | 144°25,600' E | 01,0 Kts | 110,7° | 623.2 |
| f20 | 16/08/2011 | 2:18:14 | 53°23,136' N | 144°25,706' E | 04,8 Kts | 196,8° | 626.2 |
| F21 | 16/08/2011 | 2:23:37 | 53°22,698' N | 144°25,462' E | 04,5 Kts | 192,5° | 626.2 |
| F22R | 16/08/2011 | 2:27:02 | 53°22,417' N | 144°25,345' E | 05,3 Kts | 186,9° | 619.9 |
| F18R | 16/08/2011 | 2:39:21 | 53°22,895' N | 144°24,929' E | 05,0 Kts | 331,6° | 613.5 |
| f23 | 16/08/2011 | 4:24:38 | 53°22,880' N | 144°25,053' E | 05,0 Kts | 151,7° | 614.4 |
| f24R | 16/08/2011 | 4:29:38 | 53°22,505' N | 144°25,419' E | 05,2 Kts | 150,3° | 624.4 |
| F25R | 16/08/2011 | 4:36:30 | 53°21,992' N | 144°25,939' E | 05,0 Kts | 152,8° | 634.5 |
| F26R | 16/08/2011 | 5:48:30 | 53°22,165' N | 144°25,567' E | 01,0 Kts | 158,1° | 628.1 |
| f27 | 16/08/2011 | 6:46:03 | 53°25,382' N | 144°23,686' E | 11,1 Kts | 347,2° | 601.8 |
| F28 | 16/08/2011 | 8:43:03 | 53°46,837' N | 144°15,143' E | 11,3 Kts | 346,6° | 730.2 |
| F29 | 16/08/2011 | 10:32:14 | 54°06,298' N | 144°07,325' E | 10,8 Kts | 345,8° | 836.5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| f30 | 16/08/2011 | 10:35:59 | 54°06,934' N | 144°07,083' E | 10,2 Kts | 347,8° | 818.2 |
| F31 | 16/08/2011 | 12:00:32 | 54°21,020' N | 144°01,430' E | 10,6 Kts | 348,5° | 480.5 |
| f32 | 16/08/2011 | 12:42:21 | 54°28,285' N | 143°58,465' E | 10,8 Kts | 347,4° | 478.2 |
| SF33 | 17/08/2011 | 3:20:46 | 54°45,094' N | 143°49,373' E | 05,4 Kts | 44,8° | 151.4 |
| f34 | 17/08/2011 | 4:00:58 | 54°44,985' N | 144°01,269' E | 10,3 Kts | 89,7° | 568.0 |
| f35 | 17/08/2011 | 12:42:52 | 54°12,523' N | 144°20,510' E | 05,5 Kts | 178,6° | 1014.7 |
| F36 | 17/08/2011 | 13:19:24 | 54°09,141' N | 144°20,508' E | 05,5 Kts | 179,9° | 1047.7 |
| F37 | 17/08/2011 | 14:22:09 | 54°11,248' N | 144°20,049' E | 05,6 Kts | 0,6° | 1019.3 |
| F38 | 17/08/2011 | 14:51:28 | 54°12,964' N | 144°19,397' E | 05,9 Kts | 177,4° | 997.2 |
| F39 | 17/08/2011 | 16:30:00 | 54°10,413' N | 144°18,725' E | 05,4 Kts | 0,4° | 1006.9 |
| F40 | 17/08/2011 | 16:49:16 | 54°12,090' N | 144°18,747' E | 05,3 Kts | 359,8° | 991.4 |
| F40a | 17/08/2011 | 16:50:00 | 54°12,153' N | 144°18,746' E | 05,2 Kts | 358,9° | 989.9 |
| F38-1 | 17/08/2011 | 21:23:49 | 54°12,917' N | 144°19,402' E | 05,0 Kts | 77,0° | 999.2 |
| F38-2 | 17/08/2011 | 21:58:01 | 54°12,922' N | 144°19,477' E | 05,0 Kts | 210,7° | 997.6 |
| F35-1 | 17/08/2011 | 23:59:41 | 54°12,546' N | 144°20,578' E | 06,8 Kts | 133,4° | 1017.8 |
| F38-3 | 18/08/2011 | 0:38:39 | 54°12,879' N | 144°19,394' E | 09,1 Kts | 79,1° | 997.6 |
| F41 | 18/08/2011 | 2:37:54 | 54°12,979' N | 144°21,564' E | 06,6 Kts | 187,9° | 1032.4 |
| F42 | 18/08/2011 | 2:40:52 | 54°12,587' N | 144°21,420' E | 08,5 Kts | 191,1° | 1033.3 |
| F43 | 18/08/2011 | 3:06:08 | 54°09,147' N | 144°20,484' E | 06,5 Kts | 188,7° | 1047.3 |
| F44R | 18/08/2011 | 3:07:51 | 54°08,991' N | 144°20,447' E | 05,4 Kts | 188,0° | 1047.3 |
| f45R | 18/08/2011 | 3:17:00 | 54°08,998' N | 144°19,985' E | 06,3 Kts | 12,0° | 1042.6 |
| F46 | 18/08/2011 | 3:21:20 | 54°09,211' N | 144°20,438' E | 05,9 Kts | 99,3° | 1044.2 |
| F47 | 18/08/2011 | 8:15:41 | 54°07,775' N | 144°04,851' E | 11,0 Kts | 161,4° | 735.2 |
| F48 | 18/08/2011 | 8:19:15 | 54°07,152' N | 144°05,228' E | 11,0 Kts | 160,1° | 754.2 |
| F49 | 18/08/2011 | 8:27:42 | 54°05,680' N | 144°06,152' E | 11,2 Kts | 159,0° | 801.1 |
| f50 | 18/08/2011 | 10:07:53 | 53°47,866' N | 144°15,699' E | 11,5 Kts | 163,7° | 766.9 |
| f51 | 18/08/2011 | 10:11:45 | 53°47,166' N | 144°16,088' E | 11,6 Kts | 162,3° | 736.5 |
| f52 | 18/08/2011 | 11:08:30 | 53°43,918' N | 144°14,094' E | 05,5 Kts | 269,4° | 589.4 |
| F53 | 18/08/2011 | 15:04:12 | 53°46,928' N | 144°15,681' E | 05,7 Kts | 268,2° | 734.7 |
| F54 | 18/08/2011 | 17:13:19 | 53°48,074' N | 144°01,681' E | 05,7 Kts | 48,0° | 351.4 |
| F55 | 18/08/2011 | 21:59:00 | 53°42,178' N | 144°12,160' E | 05,7 Kts | 162,7° | 513.0 |
| F56 | 18/08/2011 | 23:08:08 | 53°46,484' N | 144°12,252' E | 05,5 Kts | 342,9° | 667.7 |
| F56-1 | 19/08/2011 | 3:02:31 | 53°46,453' N | 144°12,208' E | 08,5 Kts | 5,0° | 667.7 |
| F56-2 | 19/08/2011 | 3:42:46 | 53°46,439' N | 144°12,199' E | 00,0 Kts | 339,6° | 666.6 |
| F57 | 19/08/2011 | 5:12:54 | 53°42,251' N | 144°12,170' E | 06,7 Kts | 180,2° | 508.3 |
| F58 | 19/08/2011 | 5:13:30 | 53°42,186' N | 144°12,172' E | 06,6 Kts | 179,2° | 512.2 |

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|---|---|---|---|---|---|---|---|
| f59 | 19/08/2011 | 7:39:51 | 53°34,183' N | 144°13,005' E | 07,1 Kts | 164,6° | 428.5 |
| F60 | 19/08/2011 | 9:34:15 | 53°30,242' N | 144°11,796' E | 09,8 Kts | 185,7° | 351.3 |
| F61 | 19/08/2011 | 13:10:25 | 53°14,998' N | 144°26,280' E | 05,4 Kts | 89,8° | 621.0 |
| F61a | 19/08/2011 | 17:28:26 | 53°16,270' N | 144°55,505' E | 10,1 Kts | 291,4° | 1491.1 |
| F63 | 19/08/2011 | 19:11:10 | 53°21,158' N | 144°30,222' E | 05,5 Kts | 272,2° | 723.8 |
| f64 | 19/08/2011 | 19:15:39 | 53°21,436' N | 144°30,024' E | 04,6 Kts | 10,5° | 718.7 |
| f62-1 | 19/08/2011 | 21:24:40 | 53°21,146' N | 144°30,411' E | 05,2 Kts | 287,9° | 732.4 |
| F65 | 19/08/2011 | 21:41:00 | 53°21,419' N | 144°30,168' E | 04,9 Kts | 297,6° | 723.4 |
| F65-1 | 19/08/2011 | 21:56:37 | 53°21,410' N | 144°30,164' E | 06,0 Kts | 171,1° | 722.3 |
| F65-2 | 19/08/2011 | 21:59:23 | 53°21,183' N | 144°30,223' E | 04,0 Kts | 173,8° | 722.3 |
| F65-3 | 19/08/2011 | 22:20:53 | 53°21,392' N | 144°30,142' E | 01,2 Kts | 20,3° | 722.3 |
| F66 | 19/08/2011 | 23:27:51 | 53°21,891' N | 144°29,663' E | 04,8 Kts | 50,8° | 716.7 |
| Artifact | 20/08/2011 | 0:33:08 | 53°22,007' N | 144°31,877' E | 00,0 Kts | 20,0° | 777.5 |
| F67 | 20/08/2011 | 4:07:05 | 53°22,695' N | 144°25,482' E | 05,4 Kts | 285.1° | 625.5 |
| F67R | 20/08/2011 | 4:15:33 | 53°22.443' N | 144°25.068' E | 05,2 Kts | 81.5° | 626.0 |
| F67-1 | 20/08/2011 | 4:19:20 | 53°22.675' N | 144°25.434' E | 04,8 Kts | 38.8° | 626.2 |
| F68R | 20/08/2011 | 6:08:12 | 53°23.076' N | 144°25.537' E | 02,6 Kts | 278.6° | 622.3 |
| F69 | 20/08/2011 | 6:54:09 | 53°22.659' N | 144°25.479' E | 06,4 Kts | 272.2° | 625.2 |
| f70 | 20/08/2011 | 9:10:22 | 53°23.106' N | 144°06.782' E | 09,2 Kts | 270.6° | 222.5 |
| f70a | 20/08/2011 | 9:13:13 | 53°23.104' N | 144°06.132' E | 06,9 Kts | 268.3° | 214.3 |
| SF71 | 20/08/2011 | 10:50:12 | 53°23.095' N | 143°51.703' E | 04,2 Kts | 261.5° | 114.9 |
| SF72 | 20/08/2011 | 11:31:47 | 53°23.105' N | 143°45.349' E | 09,9 Kts | 269.2° | 104.6 |
| SF73 | 20/08/2011 | 12:09:19 | 53°24.289' N | 143°45.266' E | 10,7 Kts | 37.4° | 106.0 |
| f76 | 20/08/2011 | 13:42:49 | 53°37.216' N | 144°01.737' E | 10,4 Kts | 36.6° | 208.7 |
| F77 | 20/08/2011 | 15:32:59 | 53°46.261' N | 144°16.073' E | 05,5 Kts | 166,6° | 672.8 |
| F78 | 20/08/2011 | 16:39:21 | 53°40,374' N | 144°18,366' E | 05,3 Kts | 166,5° | 668.5 |
| F79 | 20/08/2011 | 18:33:37 | 53°29,853' N | 144°22,440' E | 05,7 Kts | 166,8° | 614.4 |
| F82 | 20/08/2011 | 22:56:14 | 53°28,141' N | 144°24,635' E | 11,1 Kts | 164,4° | 649.8 |
| f80 | 20/08/2011 | 22:49:53 | 53°29,294' N | 144°24,092' E | 11,6 Kts | 164,6° | 654.7 |
| f84 | 20/08/2011 | 23:41:06 | 53°20,155' N | 144°28,428' E | 11,0 Kts | 163,9° | 681.4 |
| f83 | 20/08/2011 | 23:05:05 | 53°26,555' N | 144°25,390' E | 11,2 Kts | 163,7° | 650.8 |
| f85 | 21/08/2011 | 1:11:35 | 53°03,965' N | 144°36,071' E | 11,9 Kts | 165,2° | 755.0 |
| F86 | 21/08/2011 | 1:23:38 | 53°01,793' N | 144°37,003' E | 10,8 Kts | 165,3° | 761.7 |
| F87 | 21/08/2011 | 2:51:23 | 52°46,721' N | 144°45,394' E | 10,4 Kts | 143,7° | 787.6 |
| F88 | 21/08/2011 | 3:21:18 | 52°42,526' N | 144°50,252' E | 10,3 Kts | 144,1° | 824.9 |
| F3-1 | 22/08/2011 | 3:23:05 | 50°08,998' N | 145°41,933' E | 05,1 Kts | 149,1° | 584.8 |

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|---|---|---|---|---|---|---|---|
| SF90 | 23/08/2011 | 18:05:19 | 47°40,437' N | 144°18,139' E | 01,7 Kts | 38,2° | 211.8 |
| SF90-1 | 23/08/2011 | 18:23:22 | 47°40,410' N | 144°18,109' E | 04,2 Kts | 281,6° | 212.5 |
| SF90-2 | 23/08/2011 | 18:51:41 | 47°40,405' N | 144°18,087' E | 00,0 Kts | 18,3° | 212.5 |
| SF90-3 | 23/08/2011 | 19:21:49 | 47°40,416' N | 144°18,082' E | 00,0 Kts | 18,3° | 211.5 |
| SF90-4 | 23/08/2011 | 19:54:04 | 47°40,410' N | 144°18,083' E | 01,1 Kts | 49,6° | 212.9 |
| SF91 | 23/08/2011 | 22:48:32 | 47°41,307' N | 144°48,024' E | 08,4 Kts | 315,7° | 157.2 |
| SF91-1 | 23/08/2011 | 23:16:51 | 47°41,267' N | 144°47,889' E | 01,9 Kts | 39,1° | 158.6 |
| SF92 | 24/08/2011 | 0:06:24 | 47°41,487' N | 144°47,649' E | 03,7 Kts | 274,3° | 159.4 |
| F93 | 24/08/2011 | 0:16:42 | 47°40,356' N | 144°47,062' E | 08,5 Kts | 194,7° | 255.7 |
| f94 | 24/08/2011 | 7:05:24 | 47°26,589' N | 143°43,788' E | 09,3 Kts | 257,0° | 559.8 |
| F1-1 | 24/08/2011 | 7:21:17 | 47°23,987' N | 143°43,523' E | 10,1 Kts | 176,6° | 730.2 |
| F95 | 24/08/2011 | 9:27:32 | 47°03,876' N | 143°52,954' E | 10,1 Kts | 140,8° | 1063.4 |
| F96 | 24/08/2011 | 12:27:32 | 46°34,789' N | 143°48,512' E | 10,6 Kts | 192,9° | 228.5 |
| f97 | 24/08/2011 | 13:28:11 | 46°24,564' N | 143°45,172' E | 10,0 Kts | 192,9° | 212.7 |

F – flares distinctly visible, f – flares weakly visible, SF area shallow water flare, R – right channel.

# 3. SAMPLING AND ANALYSES

## 3.1. CTD Survey and Coring Operation

*N. Nikolaeva, E. Korovitskaya*

Table 3.1.1 Station list of LV56 (SSGH Project 2011 cruise)

| Date 2011 | Station № | Time (ship's), start -on bottom-finish | Duration min. | Latitude, N | Longitude, E | Water Depth, m | Core Length cm | Remarks |
|---|---|---|---|---|---|---|---|---|
| 16.08 | LV56-01HC | 09:27<br>09:44<br>09:54 | 27 | 53°23.106’ | 144°25.512’ | 624 | 360 | Holocene-L. Pleistocene section with traces of gas outflow, aggregates of glendonite crystals. |
| 16.08 | LV56-02CTD | 10:07<br>10:21<br>10:42 | 35 | 53°23.146’<br>53°23.170’<br>53°23.157’ | 144°25.763’<br>144°25.849’<br>144°25.798’ | 641 | | Vertical CTD profiling. 1=631 m, 2=610 m, 3=550 m, 4=500 m, 5=400 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 16.08 | LV56-03HC | 11:06<br>11:29<br>11:38 | 32 | 53°23.139’ | 144°25.576’ | 623 | 335 | L. Pleistocene section, gas hydrates, carbonate concretions. |
| 16.08 | LV56-04CTD | 12:01<br>12:15<br>12:35 | 34 | 53°23.062’<br>53°23.178’<br>53°23.103’ | 144°25.720’<br>144°25.738’<br>144°25.672’ | 636 | | Vertical CTD profiling. 1=625 m, 2=610 m, 3=550 m, 4=500 m, 5=400 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 16.08 | LV56-05HC | 14:04<br>14:15 | 11 | 53°22.865’ | 144°24.957’ | 613 | 376 | Holocene-L. Pleistocene section with traces of gas outflow, carbonate concretions. |
| 16.08 | LV56-06CTD | 14:22<br>14:39<br>14:58 | 36 | 53°22.975’<br>53°23.101’<br>53°23.276’ | 144°24.808’<br>144°24.692’<br>144°24.608’ | 606 | | Vertical CTD profiling. 1=595 m, 2=595 m, 3=550 m, 4=500 m, 5=400 m, 6=300 m, 7=300 m, 8=200 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m (empty bathometer – it is not closed). |
| 16.08 | LV56-07HC | 16:14<br>16:23 | 9 | 53°21.860’ | 144°26.050’ | 632 | 228 | Carbonate concretions. |
| 16.08 | LV56-08CTD | 16:41<br>16:54<br>17:15 | 34 | 53°22.120’<br>53°22.204’<br>53°22.333’ | 144°25.751’<br>144°25.468’<br>144°25.043’ | 620 | | Vertical CTD profiling. 1=615 m, 2=610 m, 3=550 m, 4=500 m, 5=400 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 17.08 | LV56-09HC | 15:52<br>16:05<br>16:25 | 33 | 54°44.935’ | 144°09.698’ | 740 | | Only some pebbles, gravel and coarse sand were found in the catcher. |

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|---|---|---|---|---|---|---|---|---|
| 17.08 | LV56-10CTD | 17:05<br>17:20<br>17:38 | 33 | 54°43.567'<br>54°43.411'<br>54°43.241' | 144°09.866'<br>144°09.970'<br>144°10.031' | 747 | | Vertical CTD profiling. 1=736 m, 2=730 m, 3=650 m, 4=550 m, 5=450 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m (empty bathometer – it is not closed). |
| 18.08 | LV56-11HC | 9:26<br>9:36<br>9:50 | 24 | 54°12.914' | 144°19.456' | 1000 | 484 | Holocene section with traces of gas outflow. |
| 18.08 | LV56-12CTD | 09:59<br>10:18<br>10:41 | 42 | 54°12.962'<br>54°12.963'<br>54°12.999' | 144°19.504'<br>144°19.304'<br>144°19.300' | 994 | | Vertical CTD profiling. 1=983 m, 2=975 m, 3=900 m, 4=800 m, 5=500 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 18.08 | LV56-13HC | 11:51<br>12:18<br>12:33 | 42 | 54°12.517' | 144°20.632' | 1015 | 379 | Holocene section, Calyptogena shells. |
| 18.08 | LV56-14CTD | 12:45<br>13:05<br>13:26 | 41 | 54°12.659'<br>54°13.084'<br>54°12.937' | 144°21.209'<br>144°21.127'<br>144°21.197' | 1024 | | Vertical CTD profiling. 1=1012 m, 2=1000 m, 3=900 m, 4=700 m, 5=500 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 18.08 | LV56-15HC | 14:49<br>15:14<br>15:26 | 37 | 54°09.145' | 144°20.468' | 1045 | 368 | Holocene section – background. |
| 18.08 | LV56-16CTD | 15:38<br>15:59<br>16:24 | 46 | 54°09.282'<br>54°09.488'<br>54°09.688' | 144°20.692'<br>144°21.040'<br>144°21.161' | 1042 | | Vertical CTD profiling. 1=1032 m, 2=1020 m, 3=900 m, 4=700 m, 5=500 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 18.08 | LV56-17HC | 17:49<br>17:57<br>18:10 | 21 | 54°09.980' | 144°02.050' | 640 | 403 | Holocene section – background. |
| 18.08 | LV56-18CTD | 18:16<br>18:29<br>18:48 | 32 | 54°10.103'<br>54°10.265'<br>54°10.504' | 144°02.558'<br>144°02.801'<br>144°03.124' | 650 | | Vertical CTD profiling. 1=640 m, 2=630 m, 3=500 m, 4=400 m, 5=300 m, 6=250 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 19.08 | LV56-19HC | 14:25<br>14:41<br>14:54 | 29 | 53°46.439' | 144°12.211' | 665 | 480 | Holocene section, consolidated carbonate concretion in the bottom of core. |
| 19.08 | LV56-20CTD | 15:11<br>15:24<br>15:39 | 28 | 53°46.459'<br>53°46.428'<br>53°46.330' | 144°12.257'<br>144°12.407'<br>144°12.329' | 661 | | Vertical CTD profiling. 1=650 m, 2=640 m, 3=500 m, 4=400 m, 5=300 m, 6=250 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 19.08 | LV56-21HC | 16:45<br>16:55 | 10 | 53°42.230' | 144°12.176' | 506 | 436 | L. Pleistocene section, a lot of hydrotroilite in the lower part, a large aggregate of glendonite crystals. |

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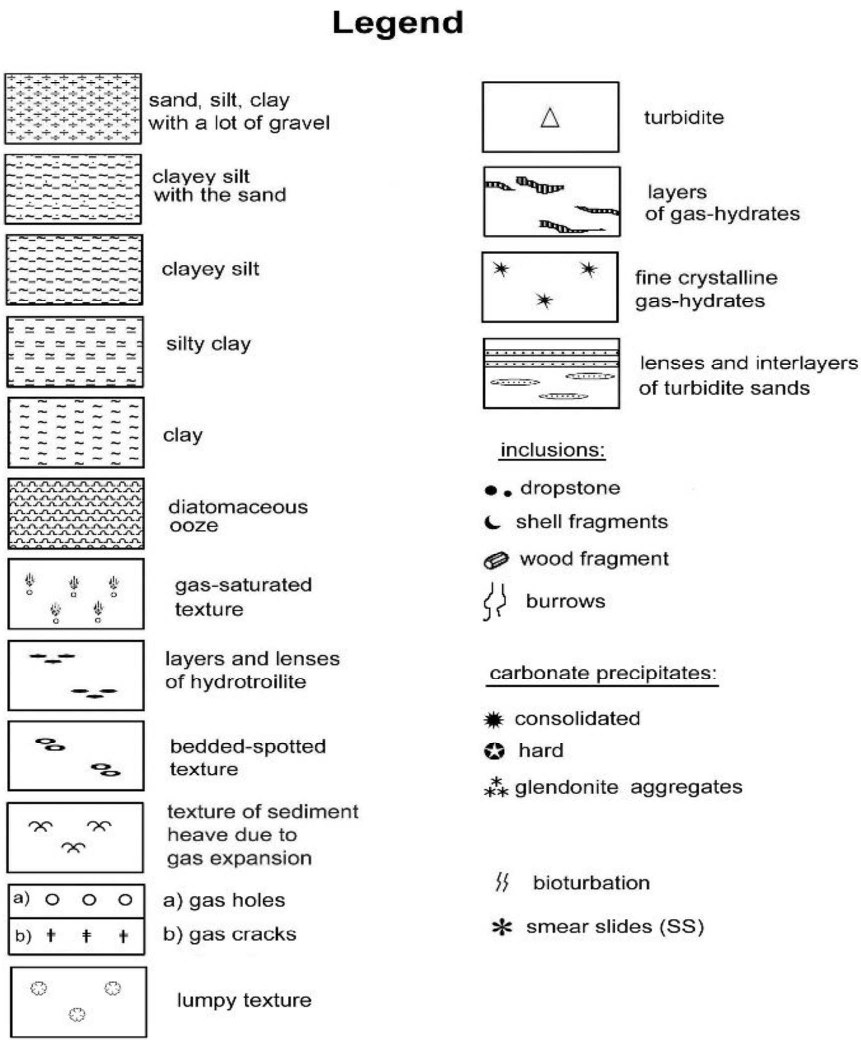
|---|---|---|---|---|---|---|---|---|
| 19.08 | LV56-22CTD | 17:06<br>17:15<br>17:31 | 25 | 53º41.950'<br>53º41.875'<br>53º41.774' | 144º11.986'<br>144º11.901'<br>144º11.777' | 507 | | Vertical CTD profiling. 1=495 m, 2=485 m, 3=400 m, 4=350 m, 5=300 m, 6=250 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 19.08 | LV56-23HC | 19:20<br>19:27 | 7 | 53º34.154' | 144º13.018' | 430 | 284 | L. Pleistocene section with traces of gas outflow, carbonate concretion. |
| 19.08 | LV56-24CTD | 19:38<br>19:46<br>20:01 | 23 | 53º34.082'<br>53º34.150'<br>53º34.195' | 144º12.646'<br>144º12.628'<br>144º12.334' | 409 | | Vertical CTD profiling. 1=400 m, 2=390 m, 3=370 m, 4=350 m, 5=300 m, 6=250 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 20.08 | LV56-25HC | 09:14<br>09:23<br>09:35 | 21 | 53º21.421' | 144º30.167' | 723 | 510 | Holocene sectionwith traces of gas outflow, carbonate concretion in the bottom of core.. |
| 20.08 | LV56-26CTD | 09:46<br>10:00<br>10:16 | 30 | 53º21.465'<br>53º21.614'<br>53º21.709' | 144º29.710'<br>144º29.534'<br>144º29.506' | 710 | | Vertical CTD profiling. 1=698 m, 2=685 m, 3=600 m, 4=500 m, 5=400 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 20.08 | LV56-27HC | 11:15<br>11:21<br>11:33 | 18 | 53º21.937' | 144º31.983' | 785 | 533 | Holocene section with traces of gas outflow. |
| 20.08 | LV56-28CTD | 11:36<br>11:50<br>12:07 | 31 | 53º21.996'<br>53º22.025'<br>53º22.121' | 144º31.897'<br>144º31.975'<br>144º32.108' | 775 | | Vertical CTD profiling. 1=764 m, 2=754 m, 3=500 m, 4=400 m, 5=350 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10= 50 m (empty bathometer – it is not closed), 11=25 m, 12=0 m (empty bathometer – it is not closed). |
| 20.08 | LV56-29HC | 12:40<br>12:55<br>13:06 | 26 | 53º21.406' | 144º30.169' | 723 | 573 | Holocene section with rare traces of gas outflow. |
| 20.08 | LV56-30CTD | 13:16<br>13:30<br>13:48 | 32 | 53º21.544'<br>53º21.591'<br>53º21.635' | 144º30.164'<br>144º30.257'<br>144º30.436' | 722 | | Vertical CTD profiling. 1=710 m, 2=700 m, 3=600 m, 4=500 m, 5=400 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m (empty bathometer – it is not closed). |
| 20.08 | LV56-31HC | 15:35<br>15:46<br>15:57 | 22 | 53º22.664' | 144º25.420' | 625 | 411 | Holocene-L. Pleistocene section, cryptocrystalline gas hydrates?., carbonate concretions. |
| 20.08 | LV56-32CTD | 16:14<br>16:26<br>16:44 | 30 | 53º22.488'<br>53º22.486'<br>53º22.475' | 144º26.102'<br>144º26.552'<br>144º27.131' | 640 | | Vertical CTD profiling. 1=626 m, 2=611 m, 3=500 m, 4=400 m, 5=350 m, 6=300 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 20.08 | LV56-33CTD | 17:17<br>17:29 | 30 | 53º23.027'<br>53º22.885' | 144º25.537'<br>144º25.666' | 624 | | Vertical CTD profiling. 1=614 m, 2=604 m (empty |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 17:47 | | 53º22.726’ | 144º25.723’ | | | bathometer – it is not closed), 3=500 m, 4=400 m, 5=300 m, 6=224 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m, 12=0 m. |
| 20.08 | LV56-34CTD | 18:32<br>18:41<br>18:52 | 20 | 53º22.997’<br>53º22.918’<br>53º22.834’ | 144º18.637’<br>144º18.659’<br>144º18.640’ | 456 | | Vertical CTD profiling. 1=444 m, 2=434 m, 3=400 m, 4=350 m (empty bathometer – it is not closed), 5=300 m, 6=250 m, 7=200 m, 8=150 m, 9=100 m, 10=75 m, 11=25 m, 12=0 m. |
| 20.08 | LV56-35CTD | 19:30<br>19:35<br>19:45 | 15 | 53º23.086’<br>53º23.097’<br>53º23.152’ | 144º11.845’<br>144º11.894’<br>144º11.812’ | 303 | | Vertical CTD profiling. 1=287 m, 2=277 m, 3=250 m, 4=200 m, 5=179 m, 6=150 m, 7=100 m, 8=75 m, 9=50 m, 10=25 m, 11=0 m. |
| 20.08 | LV56-36CTD | 20:22<br>20:26<br>20:32 | 10 | 53º23.112’<br>53º23.112’<br>53º23.124’ | 144º05.258’<br>144º05.251’<br>144º05.206’ | 202 | | Vertical CTD profiling. 1=191 m, 2=181 m, 3=150 m, 4=100 m, 5=56 m, 6=25 m, 7=11 m, 8=0 m. |
| 20.08 | LV56-37CTD | 21:08<br>21:12<br>21:16 | 08 | 53º23.095’<br>53º23.081’<br>53º23.075’ | 143º59.184’<br>143º59.147’<br>143º59.122’ | 147 | | Vertical CTD profiling. 1=136 m, 2=126 m, 3=100 m, 4=50 m, 5=25 m, 6=0 m. |
| 20.08 | LV56-38CTD | 21:57<br>21:59<br>22:04 | 07 | 53º23.060’<br>53º23.056’<br>53º23.050’ | 143º51.467’<br>143º51.449’<br>143º51.478’ | 114 | | Vertical CTD profiling. 1=103 m, 2=93 m, 3=50 m, 4=20 m, 5=10 m, 6=0 m. |
| 20.08 | LV56-39CTD | 22:46<br>22:49<br>22:53 | 07 | 53º23.111’<br>53º23.119’<br>53º23.122’ | 143º43.784’<br>143º43.798’<br>143º43.826’ | 100 | | Vertical CTD profiling. 1=89 m, 2=79 m, 3=50 m, 4=25 m, 5=10 m, 6=0 m. |
| 21.08 | LV56-40CTD | 08:58<br>09:11<br>09:28 | 30 | 53º30.989’<br>53º30.916’<br>53º30.943’ | 144º23.197’<br>144º23.273’<br>144º23.338’ | 653 | | Vertical CTD profiling. 1=643 m, 2=629 m, 3=600 m, 4=500 m, 5=400 m, 6=300 m, 7=250 m, 8=250 m, 9=150 m, 10=50 m, 11=25 m (empty bathometer – it is not closed), 12=0 (empty bathometer – it is not closed)m. |
| 21.08 | LV56-41HC | 08:35<br>08:40<br>08:51 | 16 | 53º30.958’ | 144º23.022’ | 650 | 333 | Holocene-L. Pleistocene section with traces of gas outflow, carbonate concretions. |
| 24.08 | LV56-42GR | 05:46<br>05:55 | 9 | 47º40.421’ | 144º18.093’ | 211 | | Grab has brought nothing |
| 24.08 | LV56-43CTD | 05:52<br>05:58<br>06:09 | 17 | 47º40.398’<br>47º40.346’<br>47º40.324’ | 144º18.095’<br>144º18.116’<br>144º18.100’ | 211 | | Vertical CTD profiling. 1=201 m, 2=190 m, 3=175 m, 4=150 m, 5=125 m, 6=100 m, 7=75 m, 8=50 m, 9=25 m, 10=10 m, 11=5 m, 12=0 m. |
| 24.08 | LV56-44GR | 06:24<br>06:31 | 7 | 47º40.430’ | 144º18.089’ | 211 | 20 | Coarse-grained sediment, flat crusts. |
| 24.08 | LV56-45HC | 06:54<br>07:01 | 7 | 47º40.405’ | 144º18.099’ | 211 | 173 | L. Pleistocene section with layers of turbidite sands. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 24.08 | LV56-46GR | 10:37<br>10:42<br>10:48 | 11 | 47º41.333' | 144º47.990' | 157 | 10 | Coarse-grained sediment. |
| 24.08 | LV56-47CTD | 10:50<br>10:53<br>11:01 | 11 | 47º41.386'<br>47º41.436'<br>47º41.476' | 144º47.828'<br>144º47.791'<br>144º47.768' | 161 | | Vertical CTD profiling. 1=150 m, 2=140 m, 3=125 m, 4=100 m, 5=75 m, 6=50 m, 7=40 m, 8=25 m, 9=10 m, 10=0 m. |
| 24.08 | LV56-48HC | 12:20<br>12:33<br>12:44 | 24 | 47º37.137' | 144º45.650' | 622 | 383 | Mainly L. Pleistocene section with layers of turbidite sands, carbonate concretion at bottom of core. |
| 24.08 | LV56-49CTD | 12:47<br>13:00<br>13:15 | 28 | 47º37.230'<br>47º37.306'<br>47º37.387' | 144º45.412'<br>144º45.247'<br>144º45.080' | 697 | | Vertical CTD profiling. 1=686 m, 2=674 m, 3=600 m, 4=400 m, 5=300 m, 6=250 m, 7=200 m, 8=150 m, 9=100 m, 10=50 m, 11=25 m (empty bathometer – it is not closed), 12=0 m. |

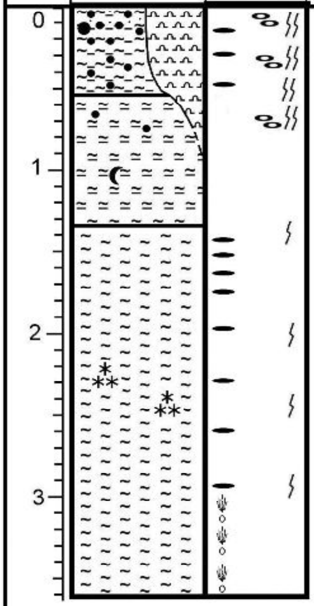
## 3.2. Core Lithology

*A. Derkachev, N. Nikolaeva*



Core description : **Lv56-01HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

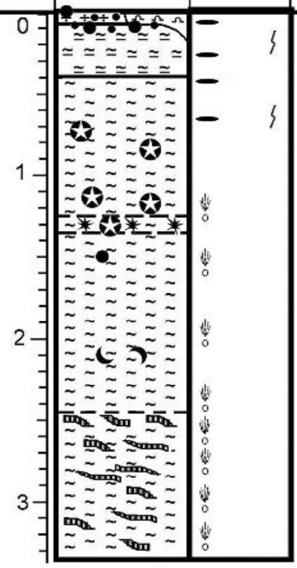
Lat: 53°23.106'
Long: 144 °25.512'
Water depth: 624 m
Recovery: 360 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|
|  | | | **Holocene-Late Pleistocene section**<br>**0-5 cm** - clayey silt with admixture of sandy particles and small gravel, olive-green, fluid, diatomaceous, with spotted texture due to intensive bioturbation;<br>**5-15 cm** - clayey silt with a lot of small gravel and rare pebble, olive-green, consolidated, spotted, with the traces of bioturbation;<br>**15-44 cm** - clayey silt with admixture of gravel in upper part and rare ones below, grayish-green, dense, with small admixture of hydrotroilite, spotted; at 17 cm - large dropstone;<br>**44-55 cm** - clayey silt with admixture of small gravel, grayish-green, soft, bioturbated;<br>**55-75 cm** - silty clay with rare gravel, greenish-gray, dense, plastic, spotted, with the traces of bioturbation;<br>**75-135 cm** - silty clay greenish-gray, dense, homogeneous, sticky, viscous; at 104 cm - small decomposed shell;<br>**135-175 cm** - clay greenish-gray, dense, homogeneous, viscous, sticky, with a lot of small spots of hydrotroilite;<br>**175-294 cm** - clay gray with light greenish hue, dense, homogeneous, sticky, viscous, with rare spots of hydrotroilite, slightly bioturbated; at 237-246 and 245-255 cm glendonite aggregates were found;<br>**294-360 cm** - clay gray, dense, homogeneous, viscous, with the traces of gas saturation - before 325 cm rare holes occur, below - sediment is cracked. | *<br>*<br>*<br>*<br>*<br><br>* |

Core description : **Lv 56-03HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 53°23.139'
Long: 144 °25.576'
Water depth: 623 m
Recovery: 335 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|



Holocene (~5 cm)-Late Pleistocene section

**0-3 cm** - mixture of the sand, silt and clay with a lot of gravel and pebble, olive-green, fluid; lower boundary is very sharp on the colour, composition and density;

**3-40 cm** - silty clay gray, moderately consolidated, homogeneous, with rare spots and lenses of hydrotroilite, a lot of gravel and pebble occur at 3-8 cm;

**40-70 cm** - clay gray, dense, viscous, sticky, with spots of hydrotroilite;

**70-115 cm** - clay gray; carbonate concretions of different size (up to 5-8 cm) occur at 70-86 cm; at 75 cm - admixture of sandy particles; rare cracks due to the gas outflow appear below 110 cm;

**115-145 cm** - clay gray, gas saturated, with specific pseudobrecciated texture; at 115-135 cm a lot of very dense gray rough carbonate concretions with zone structure are found: their inner part is dark gray (almost black) and very hard, outer part is light gray and crumbled; at 125-135 cm sediment is supersaturated with water possibly because of the decomposition of small gas hydrate particles;

**145-244 cm** - clay gray, with pseudobrecciated texture; at 150 cm - dropstone, at 210 cm - shell fragments;

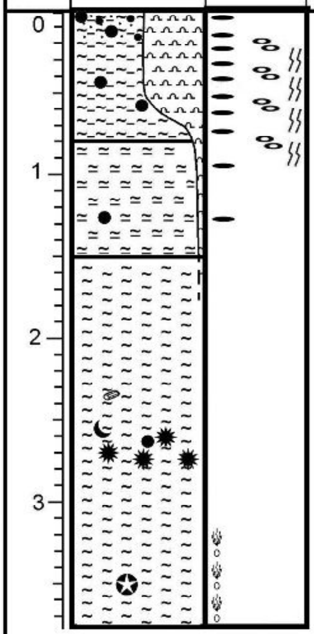
**244-258 cm** - clay gray filled up by the pieces and interlayers of gas hydrates;

**258-335 cm** - clay gray, very gas saturated; at 264-270, 285-294, 310-335 cm sediment contains gas hydrate inclusions.

Core description : **Lv 56-05HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 53°22.865'
Long: 144°24.957'
Water depth: 613 m
Recovery: 376 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|



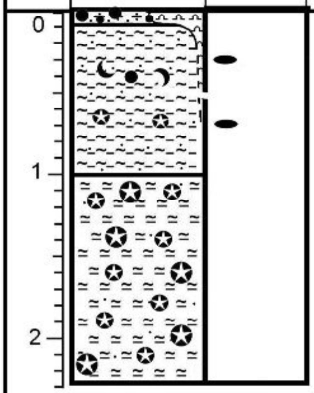

Holocene-Late Pleistocene section

**0-3 cm** - clayey silt with a lot of sand, gravel and pebble, olive-green, fluid, diatomaceous;
**3-15 cm** - clayey silt with admixture of sand, gravel and pebble, olive-green, consolidated, with rare spots of hydrotroilite; at 15 cm - dropstone;
**15-80 cm** - clayey silt dark olive-green because of a lot of hydrotroilite, dense (at 75-80 - very dense), spotted, strongly bioturbated; at 44, 58 cm - dropstone;
**80-150 cm** - silty clay grayish-green, dense (at 80-95 cm - very dense), homogeneous, plastic (below 120 cm - very viscous, sticky), with rare spots of hydrotroilite, bioturbated (at 80-100 cm - more intensively); at 124 cm - dropstone;
**150-260 cm** - clay greenish-gray, dense, homogeneous, very viscous; at 237 cm - small piece of decomposed wood, at 256 cm - decomposed shell; at 260 cm - dropstone;
**260-275 cm** - clay greenish-gray, with a lot of consolidated light green carbonate concretions;
**275-376 cm** - clay greenish-gray, gas-saturated: before 325 cm separate holes occur, below sediment is completely cracked; at 350 cm large ball-like carbonate concretion is found.

Core description : **Lv 56-07HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 53°21.860'
Long: 144°26.050'
Water depth: 632 m
Recovery: 228 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|




Holocene (~10-15 cm)-Late Pleistocene section

**0-5 cm** - mixture of the sand, silt and clay with a rare gravel and pebble, olive-green, diatomaceous, fluid;
**5-9 cm** - mixture of the sand, silt and clay with a lot of gravel and small pebble, olive-green, moderately consolidated;
**9-100 cm** - clayey silt with admixture of the sand, grayish-green, homogeneous, rare large lenses of hydrotroilite occur; at 38-46 cm - fragments of large Calyptogena shells; at 45 cm - dropstone; at 70-75 cm - small (up to 1 cm) carbonate concretions;
**100-228 cm** - silty clay with rare sandy particles, greenish-gray, homogeneous; small carbonate concretions are dispersed in whole interval, large concretions were found at 100-110, 130-140, 165-173, 196-205, 223-227 cm.

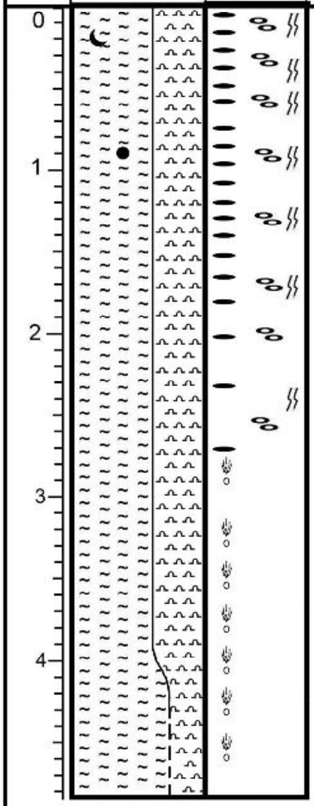
**LV56-09HC**

Only some pebbles, gravel and coarse sand were found in the hydrocorer catcher.

Core description : **Lv 56-11HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: **54º12.914'**
Long: **144º19.456'**
Water depth: **1000 m**
Recovery: **484 cm**

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|




Holocene section

**0-10 cm** - clay olive-green, fluid (diatomaceous ooze), with interlayers of hydrotroilite;

**10-40 cm** - clay olive-green, very soft (diatomaceous ooze), bedded-spotted because of hydrotroilite enrichment, weakly bioturbated; at 20 cm - Calyptogena;

**40-60 cm** - clay olive-green, moderately soft, enriched with hydrotroilite (especially at 40-56 cm - here sediment has almost black colour), bioturbated, with clear expressed bedded-spotted texture;

**60-190 cm** - clay olive-green, weakly consolidated, with numerous interlayers of hydrotroilite (especially at 77-106, 118-125, 140-160, 170-182 cm) amount of which is gradually decreased below 182 cm, bioturbated, with specific bedded-spotted texture; at 90 cm - dropstone;

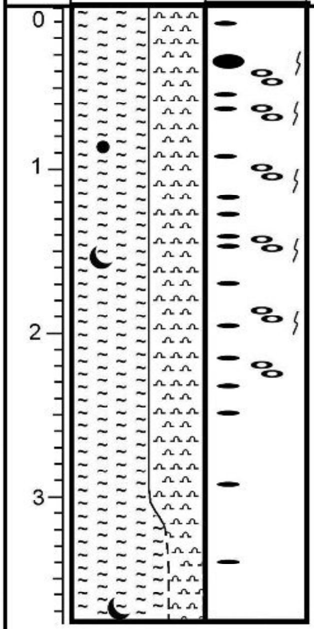
**190-275 cm** - clay olive-green, moderately consolidated, with smaller amount of hydrotroilite interlayers and rare traces of bioturbation (downwards the amount of both is decreased), weakly bedded-spotted; the first holes connected with gas outflow appear in the bottom of interval;

**275-484 cm** - clay olive-green, saturated with gas; all sediment of this interval is completely cracked because of gas outflow; strong H2S odor.

Core description : **Lv 56-13HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 54°12.517'
Long: 144°20.632'
Water depth: 1015 m
Recovery: 379 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|



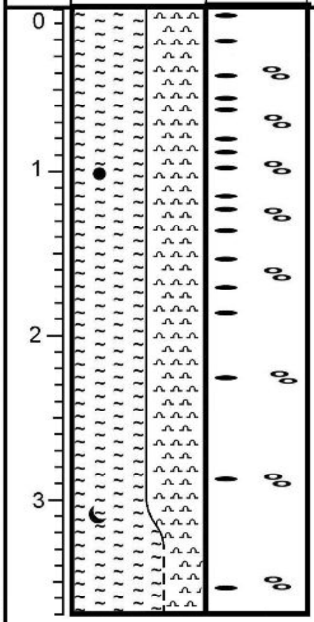

Holocene section

**0-17 cm** - clay olive-green, fluid before 5 cm and very soft below, with rare admixture of hydrotroilite;
**17-34 cm** - clay olive-green, moderately soft; at 30-32 cm - large lens of hydrotroilite;
**34-54 cm** - clay olive-green, weakly consolidated, with rare interlayers of hydrotroilite, weakly bedded;
**54-200 cm** - clay olive-green, moderately consolidated, with a numerous interlayers and lenses of hydrotroilite (especially at 60-65, 115-125, 140-143 cm), bedded-spotted, weakly bioturbated; amount of hydrotroilite is progressive decreased downwards; at 87 cm - dropstone; at 153-163 cm - a large Calyptogena shell;
**200-379 cm** - clay olive-green, consolidated, with hydrotroilite interlayers before 245 cm (below only rare lenses occur), weakly bedded in upper part; Calyptogena was found in the core catcher.

Core description : **Lv 56-15HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 54º09.145'
Long: 144º20.468'
Water depth: 1045 m
Recovery: 368 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|



### Holocene section

**0-8 cm** - clay olive-green, fluid, with rare small hydrotroilite lenses;

**8-23 cm** - clay olive-green, very soft, with rare small hydrotroilite lenses;

**23-50 cm** - clay olive-green, moderately soft, at 37-44 cm - bedded-spotted because of hydrotroilite interlayers;

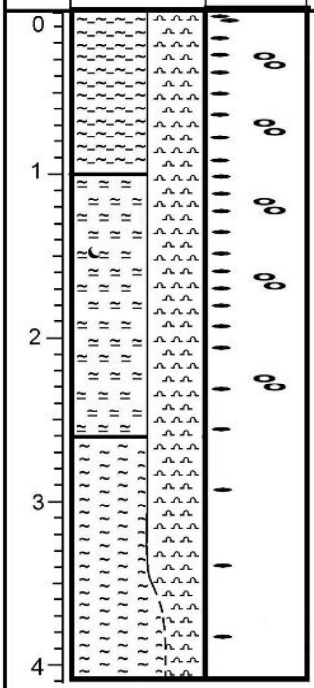
**50-250 cm** - clay olive-green, moderately consolidated, bedded-spotted before 125 cm (especially at 60-70, 83-88, 95-100, 120-125 cm) and bedded at 125-186 cm that is due to the presence of hydrotroilite interlayers; at 100 cm - dropstone;

**250-368 cm** - clay olive-green, consolidated, lenticular-spotted; at 313 cm - decomposed shell was found.

Core description : **Lv 56-17HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 54º09.980'
Long: 144º02.050'
Water depth: 640 m
Recovery: 403 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|



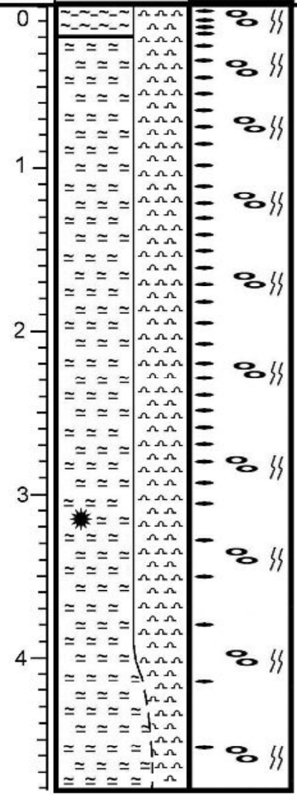

Holocene section

**0-2 cm** - clayey silt olive-green, fluid, enriched with hydrotroilite;
**2-100 cm** - clayey silt olive-green with dark hue, very soft before 10 cm, below - moderately soft; enriched with hydrotroilite, bedded-spotted;
**100-260 cm** - silty clay (or clay) olive green with dark hue, weakly consolidated, with numerous interlayers and lenses of hydrotroilite amount of which is gradually decreased downwards, bedded-spotted; at 146 cm - shell fragment;
**260-403 cm** - clay olive-green, moderately consolidated, with rare lenses and spots of hydrotroilite.

Core description : **Lv LV56-19HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 53°46.439'
Long: 144°12.211'
Water depth: 665 m
Recovery: 480 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|

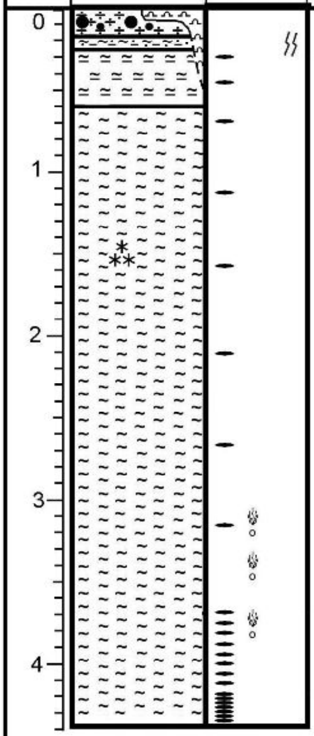



Holocene section

**0-3 cm** - clayey silt dark olive-green, fluid, enriched with hydrotroilite;
**3-18 cm** - clayey silt very dark olive-green, soft, with a lot of hydrotroilite, spotted, bioturbated;
**18-50 cm** - silty clay dark olive-green, moderately consolidated, enriched with hydrotroilite, lenticular-spotted, bioturbated;
**50-310 cm** - silty clay dark olive-green, consolidated, with a lot of hydrotroilite, lenticular-spotted (rarely - bedded-spotted), bioturbated; intervals 110-196, 210-255, 296-304 cm are more enriched with hydrotroilite, and downwards its amount is gradually decreased;
**310-480 cm** - silty clay olive-green, consolidated, with rare lenses and spots of hydrotroilite, lenticular-spotted, weakly bioturbated; at 310-313 cm - large consolidated carbonate concretion of primary stage of formation.

| Core description : **Lv LV56-21HC**<br>Cruise/Leg: RV Akademik M.A.Lavrentyev 56 | Lat: 53°42.230'<br>Long: 144°12.176'<br>Water depth: 506 m<br>Recovery: 436 cm |
|---|---|

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|




Holocene (~15 cm)-Late Pleistocene section

**0-17 cm** - mixture of the sand, silt and clay with a lot of gravel and pebbles, olive-green with gray hue, soft, diatomaceous;

**17-25 cm** - clayey silt with admixture of sandy particles, dark greenish-gray, bioturbated;

**25-60 cm** - silty clay gray, homogeneous, moderately consolidated, with rare small lenses of hydrotroilite, plastic;

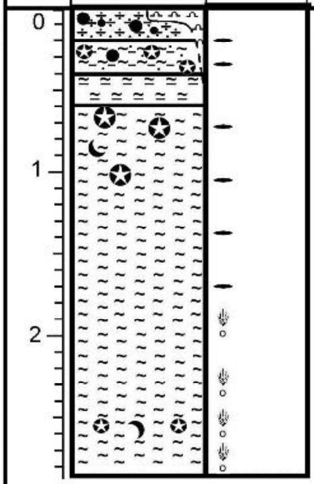
**60-370 cm** - clay gray, moderately consolidated, homogeneous, with rare small spots of hydrotroilite, plastic, viscous; below 300 cm the traces of gas saturation appear; very large (~ 8 cm of the size) aggregate of grown together glendonite crystals was found at 145-155 cm;

**370-436 cm** - interval of different colour - gray clay is impregnated by black hydrotroilitic sediment that provides clear visible spotted-bedded texture; below 420 cm amount of hydrotroilite is increased, and in total lower part of interval becomes black.

Core description : **Lv 56-23HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 53°34.154'
Long: 144°13.018'
Water depth: 430 m
Recovery: 284 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|



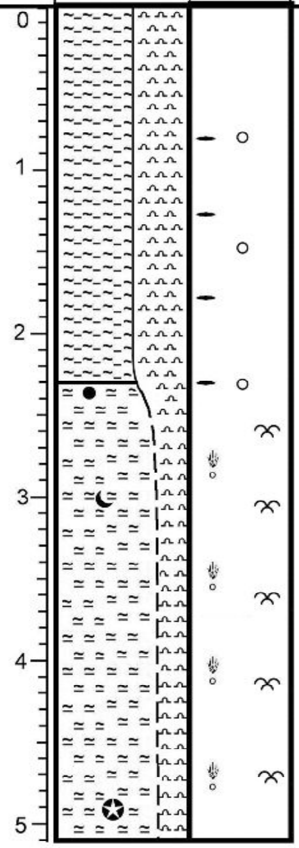

### Holocene (~10 cm)-Late Pleistocene section

**0-10 cm** - mixture of the sand, silt and clay with a lot of gravel and pebbles, olive-green, fluid, diatomaceous;
**10-20 cm** - mixture of silt, sand and clay, grayish-green, moderately consolidated;
**20-40 cm** - clayey silt with admixture of sandy particles, greenish-gray, consolidated, with rare lenses of hydrotroilite; at 25-40 cm small carbonate concretions are dispersed; at 30 cm - dropstone;
**40-60 cm** - silty clay gray, consolidated, plastic;
**60-170 cm** - clay gray, consolidated, homogeneous, with rare lenses of hydrotroilite; large branchy very dense zone carbonate concretions of size up to 12 cm were found at 65, 70, 106 cm; at 87 cm - small shells;
**170-284 cm** - clay gray, gas saturated, intensity of it is increased downwards, with characteristic pseudobrecciated texture; at 255 cm - small ball-like carbonate concretions and small shells.

Core description : **Lv LV56-25HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 53º21.421'
Long: 144º30.167'
Water depth: 723 m
Recovery: 510 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|




Holocene section

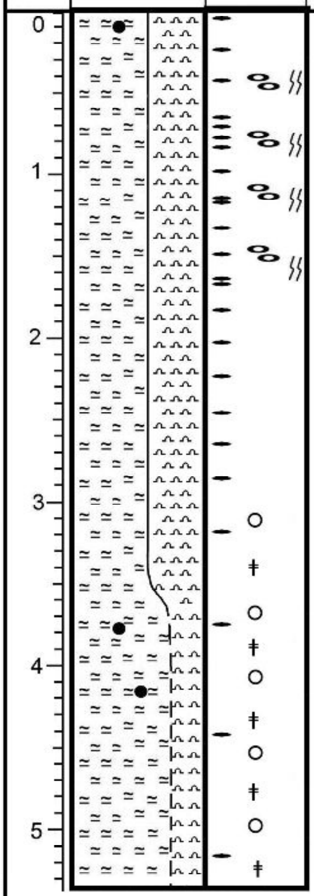
**0-3 cm** - clayey silt olive-green, fluid;
**3-35 cm** - clayey silt olive-green, soft, homogeneous;
**35-80 cm** - clayey silt olive-green, moderately consolidated; rare holes due to gas outflow appear below 70 cm;
**80-230 cm** - clayey silt olive-green, consolidated, with small lenses of hydrotroilite, with rare gas holes;
**230-510 cm** - silty clay grayish-green, consolidated, homogeneous; the traces of sediment heaving as a result of gas presence occur from 260 cm up to bottom of core; below 316 cm sediment is gradually cracked and it has pseudobrecciated texture; at 235 cm - dropstone; at 304 cm - shell; at 480-490 cm - a large (up to 9 cm) oval carbonate concretion (dense inside, crumbling outside).

SS: * * *

Core description : **Lv LV56-27HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: **53º21.937'**
Long: **144º31.983'**
Water depth: **785 m**
Recovery: **533 cm**

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|



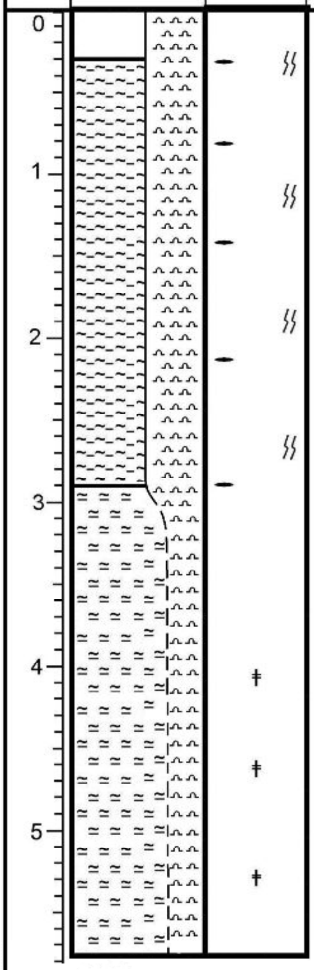

Holocene section

**0-2 cm** - silty clay olive-green, fluid;
**2-47 cm** - silty clay olive-green, soft, homogeneous, with rare small lenses of hydrotroilite; at 12 cm - dropstone;
**47-175 cm** - silty clay olive-green, moderately consolidated, with numerous lenses and spots of hydrotroilite (especially at 67-70, 76-81, 114-116, 161-167 cm), lenticular-spotted, weakly bioturbated;
**175-533 cm** - silty clay olive-green, moderately consolidated, with lenses of hydrotroilite before 286 cm, below their amount is decreased, and sediment becomes more homogeneous; holes and cracks connected with gas outflow appear at 310 cm, and downwards their amount is some increased; at 380, 416 cm - dropstone.

Core description : **Lv LV56-29HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 53º21.406'
Long: 144º30.169'
Water depth: 723 m
Recovery: 573 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|




Holocene section

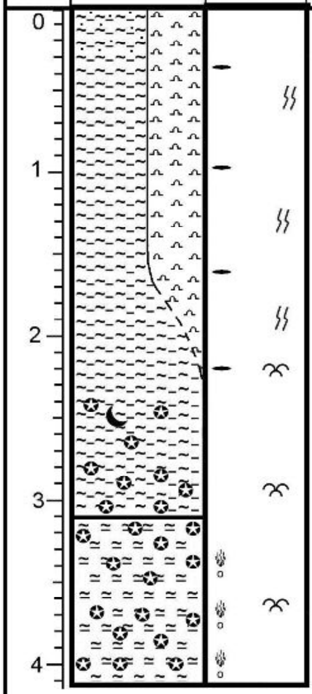
Upper 30 cm of sediment were lost because they leaved plastic liner, reached head of hydrocorer and remained in it.

**30-290 cm** - clayey silt (or silty clay) olive-green, moderately consolidated, homogeneous; downwards gray hue appears in sediment colour; rare lenses of hydrotroilite and traces of bioturbation occur;
**290-573 cm** - silty clay grayish-green, consolidated, homogeneous; rare cracks connected with gas outflow are marked at 400-573 cm.

Core description : **Lv LV56-31HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev **56**

Lat: **53°22.664'**
Long: **144°25.420'**
Water depth: **625 m**
Recovery: **411 cm**

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|




## Holocene-Late Pleistocene section

**0-5 cm** - clayey silt with a lot of sand, olive-green, fluid, diatomaceous;

**5-25 cm** - clayey silt with admixture of sand, olive-green, soft, terrigenous-diatomaceous;

**25-220 cm** - clayey silt with admixture of sandy particles, olive-green with grayish hue downwards, dense, with rare lenses of hydrotroilite and moderately bioturbation; lower boundary is sinuous and very sharp on density;

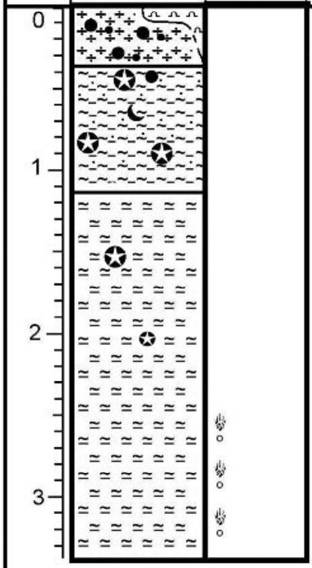
**220-310 cm** - clayey silt gray, very water saturated (especially at 220-275 cm), here and there sediment is heaving probably because of decomposition of cryptocrystalline gas hydrates; at 250 cm - very large fragments (up to 9 cm of length) of Calyptogena shell covered by very hard carbonate crust by the thickness of about 1 cm were found; one more large Calyptogena shell (up to 12 cm of length) was broken and its fragments were removed from this depth below up to 310 and 345 cm under intrusion of hydrocorer in sediment, these fragments were covered by thick hard carbonate crust (on both internal and outward surfaces) as well; at 240-310 cm - abundance of angular dense carbonate concretions (especially at 280-310 cm);

**310-411 cm** - silty clay gray, consolidated, gas saturated with pseudobrecciated texture below 340 cm; a lot of angular, branchy dense carbonate concretions were found in whole interval (especially at 310-340, 370-410 cm).

Core description : **Lv 56-41HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 53°30.958'
Long: 144°23.022'
Water depth: 650 m
Recovery: 333 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|




Holocene (~10 cm)-Late Pleistocene section

**0-3 cm** - mixture of sand, silt and clay with admixture of small pebble and gravel, olive-green, fluid;

**3-8 cm** - mixture of sand, silt and clay with admixture. of pebble and gravel, grayish-green, soft;

**8-36 cm** - mixture of silt, sand and clay with rare pebble and gravel, grayish-green, moderately consolidated;

**36-112 cm** - clayey silt with small admixture of sandy particles, grayish-green, moderately consolidated (here and there - dense), homogeneous; at 42 cm - a large dropstone with stuck to it tubular carbonate concretion; at 64 cm - small Calyptogena shell; at 84-90 cm - angular carbonate concretion up to 9 cm of size;

**112-165 cm** - silty clay (or clay) gray, moderately consolidated; at 150-160 cm - spindle-like carbonate concretion up to 12 cm of the length;

**165-333 cm** - silty clay (or clay) gray, moderately consolidated; gas saturation with the cracks of pseudobrecciated texture appears below 260 cm; at 200 cm - small carbonate concretion.

**LV56-42GR**

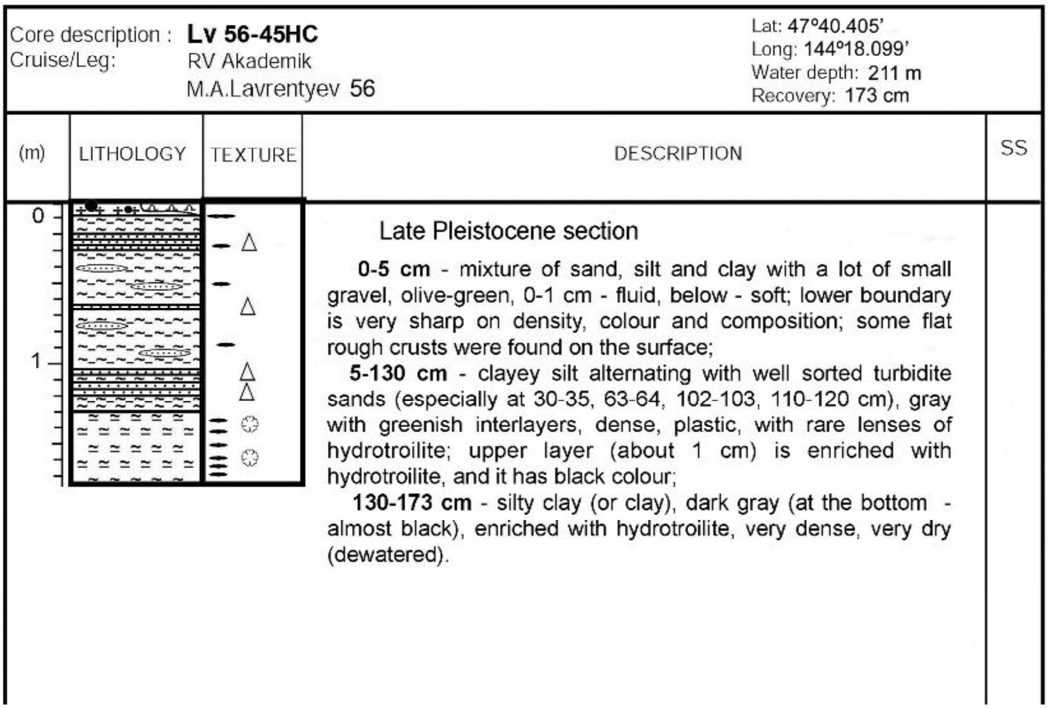
Grab has brought nothing (it is not closed).

**LV56-44GR**

**0-7 cm** – silty sand with a lot of gravel and pebble, olive-green with grayish hue, a large Calyptogena shell was found on the surface (very old, brittle), it was covered with different sea organisms; some very flat dense rough crusts were discovered here, their inner surface is brownish-yellow and they have Fe-Mn coat from the outside; worm tubes were found here as well;

**7-10 cm** – silty sand with rare gravel, black (enriched with hydrotroilite), lower boundary is very sharp on colour, density and composition;

**10-20 cm** – silty clay gray, dense, homogeneous.



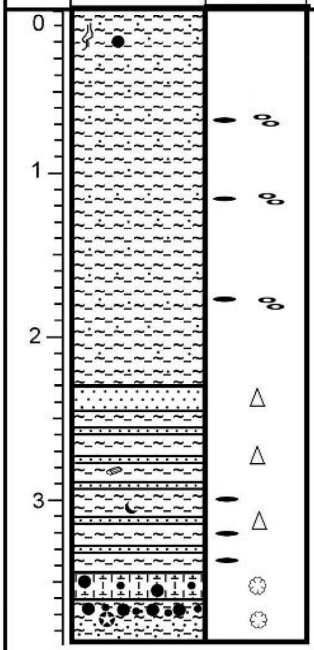

**LV56-46GR**

**0-10 cm** – silty sand with a lot of gravel and pebble, before 5 cm – grayish-green, below – gray.

Core description : **Lv 56-48HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 56

Lat: 47°37.137'
Long: 144°45.650'
Water depth: 622 m
Recovery: 383 cm

| (m) | LITHOLOGY | TEXTURE | DESCRIPTION | SS |
|---|---|---|---|---|




Late Pleistocene section

**0-5 cm** - clayey silt olive-green with grayish hue, fluid;
**5-15 cm** - clayey silt with admixture of sandy particles, grayish-green, soft;
**15-50 cm** - clayey silt with small admixture of sandy particles, grayish-green, consolidated, homogeneous; at 16 cm - a long trace of worm crawling; at 20 cm - dropstone;
**50-230 cm** - clayey silt with small admixture of sandy particles, grayish-green, consolidated, with rare small lenses of hydrotroilite, weakly spotted;
**230-245 cm** - turbidite layer; it consists of fine-grained well sorted sand, greenish-gray, dense;
**245-344 cm** - clayey silt alternating with well sorted turbidite sands, very dense, greenish-gray, before 295 cm - with rare lenses of hydrotroilite, below their amount is increased; at 280 cm - wood fragment; at 302 cm - decomposed shell;
**344-360 cm** - layer consists of coarse-grained sediment: mixture of sand, silt, gravel and pebble (rarely), greenish-gray, very dense (dewatered);
**360-383 cm** - clayey silt with a lot of sand, dark greenish-gray, very dense; at 367-370 cm - layer enriched with gravel and pebble; a large (6x5 cm) dense rough carbonate concretion of oval shape is found at 368-373 cm.

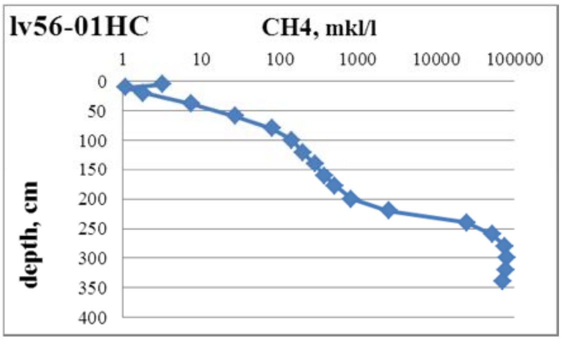
## 3.3. Core Analyses

### 3.3.1. Gas Analysis (POI)

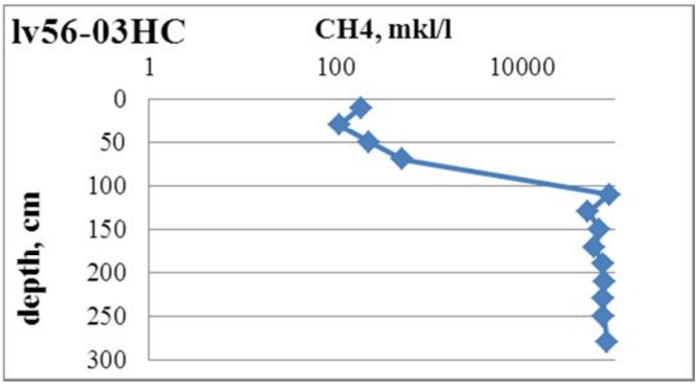
*A. Obzhirov, O. Vereshchagina, E. Korovitskaya*

**Explanation for this section is combined with and included in 3.4.2. Gas Geochemical Investigation.**

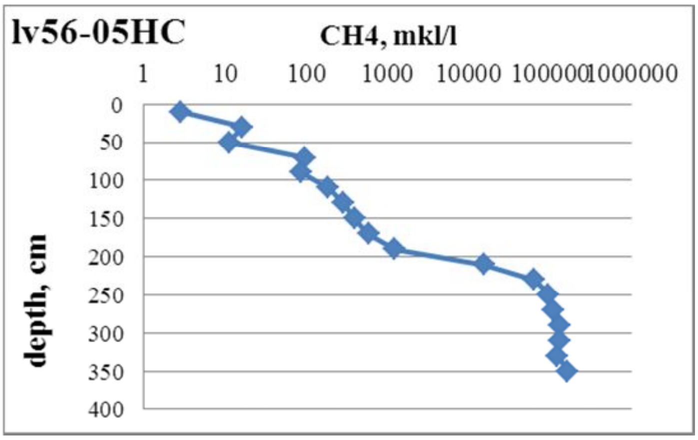
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| station | 5 | **3** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 9.10 |
| lv56-01HC | 10 | **1** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 8.16 |
| | 20 | **2** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 2.79 |
| Latitude | 38 | **8** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 1.93 |
| 53°23,106 | 59 | **27** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 1.88 |
| | 80 | **80** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 3.03 |
| Longitude | 100 | **144** | 0.00000 | 0.00017 | 0.00000 | 0.00000 | 2.90 |
| 144°25,512 | 121 | **202** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 3.18 |
| | 140 | **284** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 4.03 |
| | 160 | **376** | 0.00000 | 0.00042 | 0.00000 | 0.00000 | 3.45 |
| | 178 | **515** | 0.00000 | 0.00002 | 0.00000 | 0.00000 | 5.17 |
| | 200 | **834** | 0.00000 | 0.00063 | 0.00000 | 0.00000 | 6.41 |
| | 220 | **2511** | 0.00000 | 0.00064 | 0.00000 | 0.00000 | 7.04 |
| | 240 | **24772** | 0.00000 | 0.00089 | 0.00000 | 0.00000 | 7.67 |
| | 260 | **52472** | 0.00000 | 0.00085 | 0.00000 | 0.00022 | 9.19 |
| | 280 | **76372** | 0.00000 | 0.00106 | 0.00000 | 0.00028 | 10.22 |
| | 300 | **81961** | 0.00000 | 0.00093 | 0.00000 | 0.00032 | 10.23 |
| | 320 | **79120** | 0.00000 | 0.00085 | 0.00000 | 0.00027 | 11.87 |
| | 340 | **70631** | 0.00000 | 0.00068 | 0.00000 | 0.00029 | 12.97 |



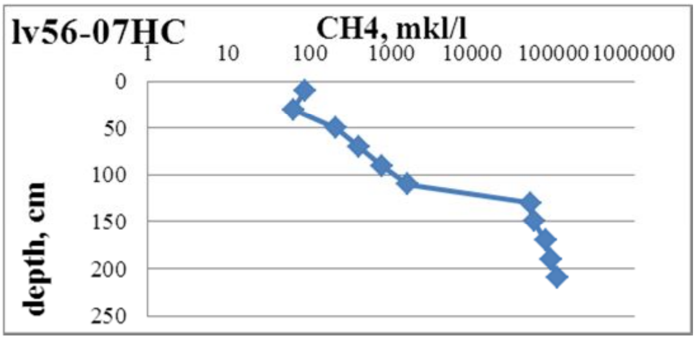
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-03HC | 10 | **185** | 0.00000 | 0.00045 | 0.00000 | 0.00000 | 0.94 |
| GasHydrate | 30 | **109** | 0.00000 | 0.00120 | 0.00000 | 0.00000 | 1.48 |
| | 50 | **230** | 0.00000 | 0.00281 | 0.00000 | 0.00000 | 1.83 |
| 53°23,139 | 70 | **525** | 0.00000 | 0.00645 | 0.00000 | 0.00000 | 2.47 |
| | 110 | **85646** | 0.00000 | 0.02506 | 0.00000 | 0.00225 | 3.39 |
| 144°25,576 | 130 | **50849** | 0.00000 | 0.01618 | 0.00000 | 0.00183 | 3.00 |
| | 150 | **67910** | 0.00000 | 0.01889 | 0.00000 | 0.00231 | 4.20 |
| | 170 | **60236** | 0.00000 | 0.01720 | 0.00000 | 0.00225 | 4.44 |
| | 190 | **73420** | 0.00000 | 0.01896 | 0.00000 | 0.00239 | 4.04 |
| | 210 | **76452** | 0.00000 | 0.01980 | 0.00000 | 0.00222 | 4.46 |
| | 230 | **74793** | 0.00000 | 0.02098 | 0.00000 | 0.00221 | 5.26 |
| | 250 | **75171** | 0.00000 | 0.04089 | 0.00000 | 0.00140 | 1.72 |
| | 280 | **82651** | 0.00000 | 0.02912 | 0.00000 | 0.00162 | 4.33 |



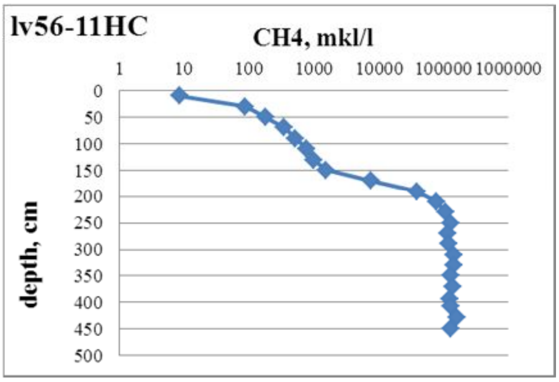
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-05HC | 10 | **3** | 0.00001 | 0.00000 | 0.00000 | 0.00000 | 8.61 |
| | 30 | **16** | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 4.86 |
| | 50 | **11** | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 4.56 |
| 53°22,865 | 70 | **96** | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 5.20 |
| | 90 | **88** | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 3.45 |
| 144°24,957 | 110 | **189** | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 4.82 |
| | 130 | **290** | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 7.28 |
| | 150 | **396** | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 9.37 |
| | 170 | **586** | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 10.09 |
| | 190 | **1251** | 0.00000 | 0.00001 | 0.00001 | 0.00001 | 13.75 |
| | 210 | **15350** | 0.00000 | 0.00018 | 0.00000 | 0.00025 | 15.71 |
| | 230 | **64434** | 0.00000 | 0.00021 | 0.00000 | 0.00037 | 18.26 |
| | 250 | **96921** | 0.00000 | 0.00021 | 0.00000 | 0.00049 | 17.77 |
| | 270 | **110270** | 0.00000 | 0.00018 | 0.00000 | 0.00054 | 12.53 |
| | 290 | **134702** | 0.00000 | 0.00016 | 0.00000 | 0.00055 | 18.38 |
| | 310 | **130801** | 0.00000 | 0.00017 | 0.00000 | 0.00053 | 18.97 |
| | 330 | **124287** | 0.00000 | 0.00017 | 0.00000 | 0.00059 | 17.87 |
| | 350 | **166198** | 0.00000 | 0.00017 | 0.00000 | 0.00065 | 21.21 |



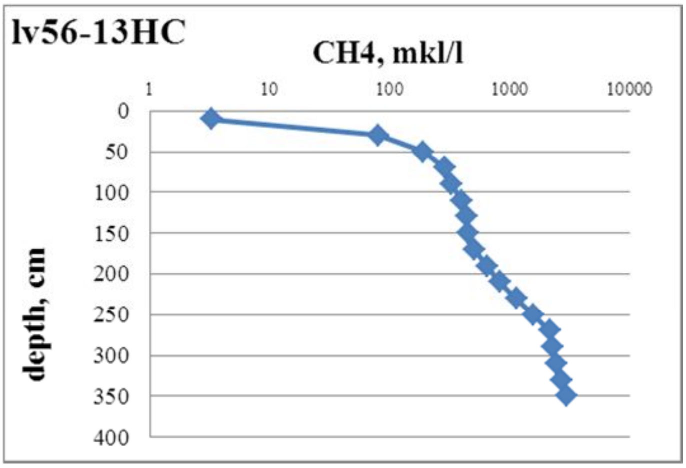
| | depth, cm | **CH4, mkl/l** | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-07HC | 10 | **87** | 0.00001 | 0.00001 | 0.00000 | 0.00000 | 2.55 |
| 227cm | 30 | **63** | 0.00000 | 0.00066 | 0.00000 | 0.00000 | 2.42 |
| | 50 | **213** | 0.00000 | 0.00189 | 0.00000 | 0.00000 | 2.97 |
| 53°21,860 | 70 | **400** | 0.00000 | 0.00340 | 0.00000 | 0.00000 | 3.59 |
| | 90 | **767** | 0.00000 | 0.00542 | 0.00000 | 0.00000 | 5.14 |
| 144°26,050 | 110 | **1628** | 0.00000 | 0.00747 | 0.00000 | 0.00020 | 5.97 |
| | 130 | **52876** | 0.00000 | 0.01048 | 0.00000 | 0.00061 | 6.53 |
| | 150 | **58234** | 0.00000 | 0.01039 | 0.00000 | 0.00076 | 6.10 |
| | 170 | **81722** | 0.00000 | 0.01147 | 0.00000 | 0.00122 | 5.48 |
| | 190 | **94931** | 0.00000 | 0.01190 | 0.00000 | 0.00123 | 4.35 |
| | 210 | **112613** | 0.00000 | 0.01246 | 0.00000 | 0.00144 | 5.45 |



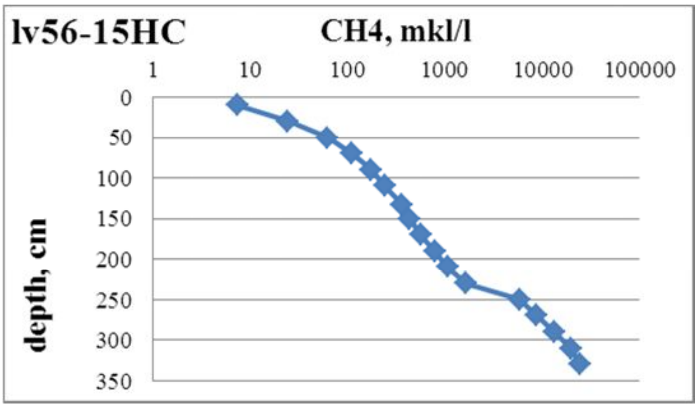
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-11HC | 10 | 9 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 5.09 |
| 484cm | 30 | 89 | 0.00010 | 0.00014 | 0.00000 | 0.00002 | 7.09 |
| swimming sed | 50 | 184 | 0.00001 | 0.00014 | 0.00000 | 0.00001 | 8.48 |
| | 70 | 355 | 0.00002 | 0.00025 | 0.00000 | 0.00002 | 10.67 |
| 54°12,914 | 90 | 530 | 0.00002 | 0.00033 | 0.00000 | 0.00002 | 13.08 |
| | 110 | 787 | 0.00002 | 0.00051 | 0.00000 | 0.00002 | 15.92 |
| 144°19,456 | 130 | 993 | 0.00002 | 0.00060 | 0.00000 | 0.00002 | 17.39 |
| | 150 | 1568 | 0.00002 | 0.00071 | 0.00000 | 0.00002 | 18.14 |
| | 170 | 7716 | 0.00002 | 0.00085 | 0.00000 | 0.00022 | 17.49 |
| | 190 | 39105 | 0.00000 | 0.00076 | 0.00000 | 0.00033 | 17.73 |
| | 210 | 77807 | 0.00000 | 0.00090 | 0.00000 | 0.00046 | 19.50 |
| | 230 | 108904 | 0.00000 | 0.00105 | 0.00000 | 0.00057 | 20.68 |
| | 250 | 128679 | 0.00000 | 0.00105 | 0.00000 | 0.00061 | 19.03 |
| | 270 | 117784 | 0.00000 | 0.00091 | 0.00000 | 0.00052 | 17.48 |
| | 290 | 120145 | 0.00000 | 0.00089 | 0.00000 | 0.00058 | 18.11 |
| | 310 | 143559 | 0.00000 | 0.00096 | 0.00000 | 0.00065 | 18.99 |
| | 330 | 147009 | 0.00000 | 0.00103 | 0.00000 | 0.00070 | 18.21 |
| | 350 | 131187 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 17.79 |
| | 370 | 140500 | 0.00000 | 0.00103 | 0.00000 | 0.00067 | 16.83 |
| | 393 | 124697 | 0.00000 | 0.00097 | 0.00000 | 0.00053 | 17.02 |
| | 408 | 129642 | 0.00000 | 0.00087 | 0.00000 | 0.00064 | 20.61 |
| | 429 | 158605 | 0.00000 | 0.00112 | 0.00000 | 0.00066 | 18.37 |
| | 450 | 131205 | 0.00000 | 0.00097 | 0.00000 | 0.00089 | 17.68 |
| lv56-11HG | 470 | 131329 | 0.00000 | 0.00066 | 0.00000 | 0.00066 | 35.33 |
| lv56-11HG | 470 | 172201 | 0.00000 | 0.00093 | 0.00000 | 0.00131 | 40.98 |



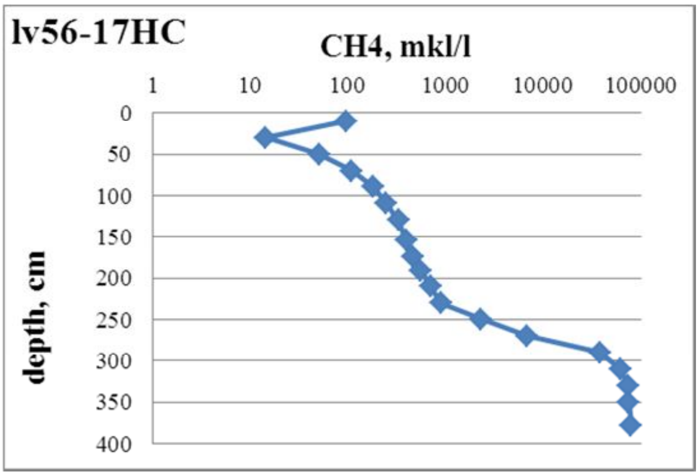
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-13HC | 10 | **3** | 0.00009 | 0.00007 | 0.00000 | 0.00004 | 5.35 |
| | 30 | **80** | 0.00005 | 0.00006 | 0.00000 | 0.00006 | 6.12 |
| | 50 | **190** | 0.00006 | 0.00016 | 0.00000 | 0.00002 | 6.92 |
| 54°12,517 | 70 | **286** | 0.00005 | 0.00019 | 0.00000 | 0.00002 | 8.13 |
| | 90 | **330** | 0.00006 | 0.00018 | 0.00000 | 0.00002 | 7.51 |
| 144°20,632 | 110 | **397** | 0.00001 | 0.00021 | 0.00000 | 0.00001 | 7.62 |
| | 130 | **437** | 0.00002 | 0.00022 | 0.00000 | 0.00002 | 7.76 |
| | 150 | **448** | 0.00001 | 0.00024 | 0.00000 | 0.00001 | 7.15 |
| | 170 | **503** | 0.00002 | 0.00027 | 0.00000 | 0.00002 | 7.73 |
| | 190 | **644** | 0.00002 | 0.00029 | 0.00000 | 0.00002 | 8.20 |
| | 210 | **826** | 0.00002 | 0.00035 | 0.00000 | 0.00002 | 8.71 |
| | 230 | **1132** | 0.00001 | 0.00046 | 0.00000 | 0.00001 | 10.49 |
| | 250 | **1560** | 0.00000 | 0.00060 | 0.00000 | 0.00002 | 11.76 |
| | 270 | **2157** | 0.00000 | 0.00081 | 0.00000 | 0.00002 | 13.42 |
| | 290 | **2302** | 0.00000 | 0.00089 | 0.00000 | 0.00019 | 14.20 |
| | 310 | **2445** | 0.00000 | 0.00089 | 0.00000 | 0.00019 | 15.30 |
| | 330 | **2712** | 0.00000 | 0.00087 | 0.00000 | 0.00020 | 15.99 |
| | 350 | **2988** | 0.00000 | 0.00089 | 0.00000 | 0.00030 | 16.60 |



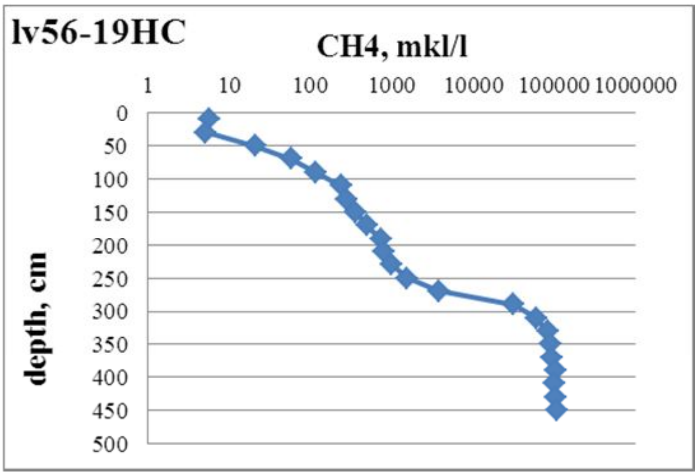
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-15HC | 10 | **8** | 0.00009 | 0.00006 | 0.00000 | 0.00003 | 5.14 |
| | 30 | **24** | 0.00009 | 0.00011 | 0.00000 | 0.00011 | 6.52 |
| | 50 | **63** | 0.00010 | 0.00011 | 0.00011 | 0.00010 | 7.24 |
| 54°09,145 | 70 | **113** | 0.00009 | 0.00013 | 0.00013 | 0.00011 | 7.96 |
| | 90 | **177** | 0.00000 | 0.00008 | 0.00000 | 0.00008 | 8.91 |
| 144°20,468 | 110 | **242** | 0.00000 | 0.00008 | 0.00000 | 0.00000 | 10.45 |
| | 133 | **366** | 0.00000 | 0.00018 | 0.00000 | 0.00007 | 9.99 |
| | 150 | **442** | 0.00002 | 0.00017 | 0.00000 | 0.00002 | 10.37 |
| | 170 | **572** | 0.00002 | 0.00022 | 0.00000 | 0.00002 | 11.71 |
| | 190 | **792** | 0.00002 | 0.00025 | 0.00000 | 0.00002 | 14.21 |
| | 210 | **1074** | 0.00001 | 0.00032 | 0.00000 | 0.00001 | 16.97 |
| | 230 | **1676** | 0.00002 | 0.00041 | 0.00000 | 0.00002 | 17.74 |
| | 250 | **5843** | 0.00000 | 0.00044 | 0.00000 | 0.00020 | 18.50 |
| | 270 | **8871** | 0.00000 | 0.00041 | 0.00000 | 0.00018 | 19.71 |
| | 290 | **13394** | 0.00000 | 0.00044 | 0.00000 | 0.00022 | 18.96 |
| | 310 | **19734** | 0.00000 | 0.00044 | 0.00000 | 0.00022 | 20.76 |
| | 330 | **24889** | 0.00000 | 0.00038 | 0.00000 | 0.00027 | 20.14 |



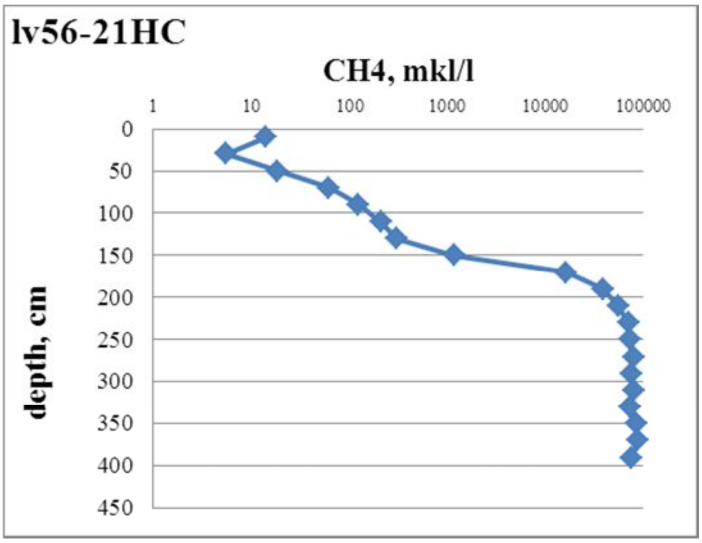
| | cm | mkl/l | nl/l | nl/l | nl/l | nl/l | ml/l |
|---|---|---|---|---|---|---|---|
| lv56-17HC | 10 | **97** | 0.00013 | 0.00004 | 0.00000 | 0.00000 | 9.81 |
| | 30 | **15** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.91 |
| | 50 | **51** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.14 |
| 54°09,980 | 70 | **110** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.79 |
| | 90 | **184** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 8.02 |
| 144°02,050 | 110 | **250** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 9.48 |
| | 130 | **328** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 10.22 |
| | 154 | **394** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 12.61 |
| | 174 | **460** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 11.59 |
| | 191 | **562** | 0.00000 | 0.00017 | 0.00000 | 0.00000 | 14.03 |
| | 210 | **700** | 0.00000 | 0.00014 | 0.00000 | 0.00000 | 15.39 |
| | 230 | **913** | 0.00000 | 0.00013 | 0.00000 | 0.00000 | 16.28 |
| | 250 | **2328** | 0.00000 | 0.00020 | 0.00000 | 0.00000 | 21.67 |
| | 270 | **6794** | 0.00000 | 0.00020 | 0.00000 | 0.00000 | 17.39 |
| | 290 | **38304** | 0.00000 | 0.00020 | 0.00000 | 0.00013 | 21.67 |
| | 310 | **62047** | 0.00000 | 0.00016 | 0.00000 | 0.00009 | 15.64 |
| | 330 | **74216** | 0.00000 | 0.00002 | 0.00000 | 0.00002 | 23.97 |
| | 350 | **75182** | 0.00000 | 0.00001 | 0.00000 | 0.00001 | 25.09 |
| | 378 | **80077** | 0.00000 | 0.00001 | 0.00000 | 0.00001 | 23.91 |



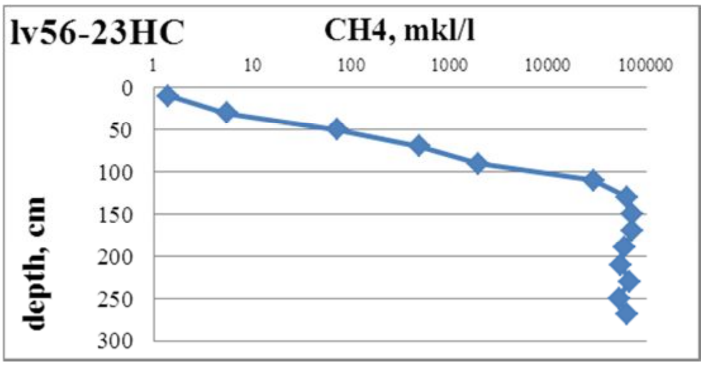
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-19HC | 10 | 6 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 8.93 |
| | 30 | 5 | 0.00010 | 0.00004 | 0.00000 | 0.00000 | 7.54 |
| | 50 | 21 | 0.00009 | 0.00011 | 0.00000 | 0.00000 | 6.44 |
| 53°46,439 | 70 | 58 | 0.00008 | 0.00006 | 0.00006 | 0.00005 | 6.33 |
| | 90 | 116 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.97 |
| 144°12,211 | 110 | 239 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 7.96 |
| | 130 | 286 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 9.31 |
| | 150 | 364 | 0.00001 | 0.00010 | 0.00000 | 0.00000 | 10.79 |
| | 170 | 498 | 0.00000 | 0.00001 | 0.00000 | 0.00000 | 12.84 |
| | 190 | 739 | 0.00000 | 0.00017 | 0.00000 | 0.00000 | 16.86 |
| | 210 | 821 | 0.00000 | 0.00018 | 0.00000 | 0.00000 | 16.13 |
| | 230 | 1009 | 0.00000 | 0.00012 | 0.00000 | 0.00000 | 17.42 |
| | 250 | 1569 | 0.00000 | 0.00016 | 0.00000 | 0.00000 | 17.73 |
| | 270 | 3842 | 0.00000 | 0.00019 | 0.00000 | 0.00000 | 19.85 |
| | 290 | 32020 | 0.00000 | 0.00022 | 0.00000 | 0.00016 | 21.93 |
| | 310 | 60481 | 0.00000 | 0.00020 | 0.00000 | 0.00022 | 12.81 |
| | 330 | 83787 | 0.00000 | 0.00018 | 0.00000 | 0.00027 | 24.72 |
| | 350 | 90522 | 0.00000 | 0.00022 | 0.00000 | 0.00020 | 24.57 |
| | 370 | 95751 | 0.00000 | 0.00022 | 0.00000 | 0.00025 | 25.28 |
| | 390 | 106456 | 0.00000 | 0.00021 | 0.00000 | 0.00026 | 26.47 |
| | 410 | 103351 | 0.00000 | 0.00027 | 0.00000 | 0.00031 | 24.69 |
| | 430 | 106469 | 0.00000 | 0.00028 | 0.00000 | 0.00022 | 24.39 |
| | 450 | 111516 | 0.00000 | 0.00015 | 0.00000 | 0.00026 | 25.05 |



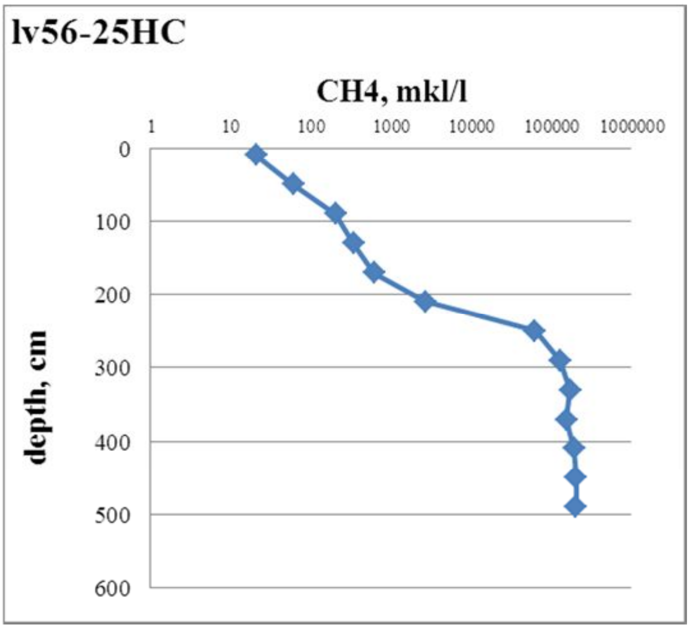
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-21HC | 10 | **14** | 0.00004 | 0.00000 | 0.00000 | 0.00000 | 4.79 |
| | 30 | **6** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.41 |
| | 50 | **19** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.78 |
| 53°42,230 | 70 | **62** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 2.10 |
| | 90 | **125** | 0.00000 | 0.00003 | 0.00003 | 0.00003 | 2.86 |
| 144°12,176 | 110 | **209** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 3.45 |
| | 130 | **309** | 0.00000 | 0.00006 | 0.00000 | 0.00025 | 4.19 |
| | 150 | **1183** | 0.00000 | 0.00006 | 0.00000 | 0.00051 | 4.87 |
| | 170 | **16375** | 0.00000 | 0.00012 | 0.00000 | 0.00058 | 6.32 |
| | 190 | **38730** | 0.00000 | 0.00008 | 0.00000 | 0.00052 | 6.75 |
| | 210 | **55721** | 0.00000 | 0.00012 | 0.00000 | 0.00041 | 7.72 |
| | 230 | **71602** | 0.00000 | 0.00014 | 0.00000 | 0.00049 | 7.61 |
| | 250 | **73064** | 0.00000 | 0.00011 | 0.00000 | 0.00043 | 7.97 |
| | 270 | **80709** | 0.00000 | 0.00008 | 0.00000 | 0.00063 | 8.27 |
| | 290 | **75534** | 0.00000 | 0.00006 | 0.00000 | 0.00054 | 10.03 |
| | 310 | **81505** | 0.00000 | 0.00007 | 0.00000 | 0.00061 | 10.64 |
| | 330 | **73268** | 0.00000 | 0.00005 | 0.00000 | 0.00055 | 8.99 |
| | 350 | **85320** | 0.00000 | 0.00007 | 0.00000 | 0.00058 | 10.52 |
| | 370 | **87563** | 0.00000 | 0.00004 | 0.00000 | 0.00055 | 11.66 |
| | 390 | **76457** | 0.00000 | 0.00005 | 0.00000 | 0.00059 | 11.83 |



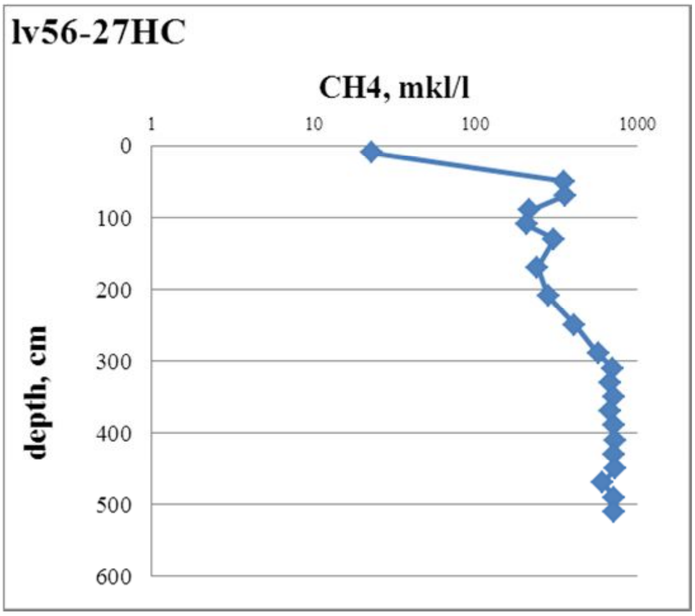
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-23HC | 10 | **1** | 0.00010 | 0.00010 | 0.00000 | 0.00000 | 2.91 |
| | 30 | **6** | 0.00009 | 0.00009 | 0.00000 | 0.00000 | 1.41 |
| | 50 | **74** | 0.00000 | 0.00042 | 0.00000 | 0.00000 | 2.31 |
| 53°34,154 | 70 | **502** | 0.00000 | 0.00253 | 0.00000 | 0.00048 | 3.86 |
| | 90 | **1961** | 0.00000 | 0.00318 | 0.00000 | 0.00063 | 4.23 |
| 144°13,018 | 110 | **28984** | 0.00000 | 0.00406 | 0.00000 | 0.00102 | 4.97 |
| | 130 | **63039** | 0.00000 | 0.00447 | 0.00000 | 0.00172 | 5.31 |
| | 150 | **71277** | 0.00000 | 0.00412 | 0.00000 | 0.00187 | 5.25 |
| | 170 | **72140** | 0.00000 | 0.00361 | 0.00000 | 0.00176 | 5.37 |
| | 190 | **59326** | 0.00000 | 0.00299 | 0.00000 | 0.00174 | 5.55 |
| | 210 | **55259** | 0.00000 | 0.00269 | 0.00000 | 0.00134 | 6.01 |
| | 230 | **67264** | 0.00000 | 0.00314 | 0.00000 | 0.00195 | 7.61 |
| | 250 | **52578** | 0.00000 | 0.00261 | 0.00000 | 0.00201 | 6.02 |
| | 268 | **62948** | 0.00000 | 0.00291 | 0.00000 | 0.00212 | 7.38 |
| lv56-23HG | 280 | **63986** | 0.00000 | 0.00342 | 0.00000 | 0.00266 | 14.63 |
| lv56-23HG | 280 | **46575** | 0.00000 | 0.00267 | 0.00000 | 0.00215 | 12.33 |



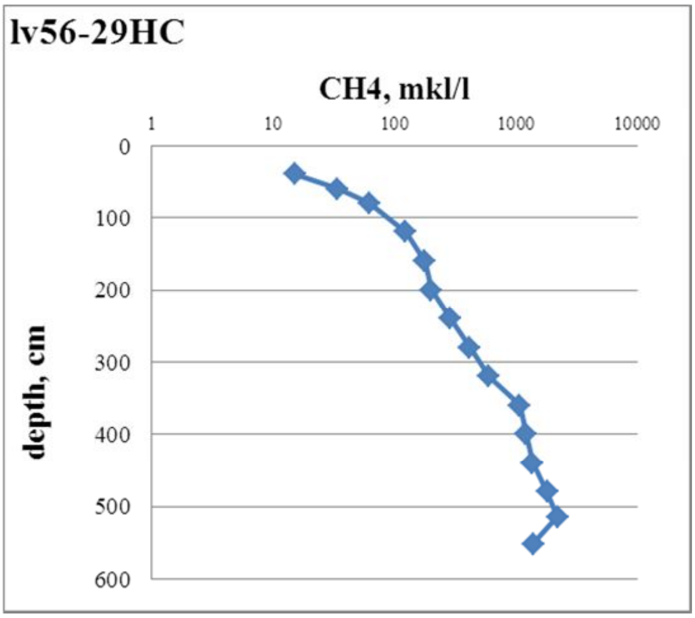
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-25HC | 10 | **21** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 8.15 |
| | 50 | **60** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 7.27 |
| | 90 | **204** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 8.76 |
| 53°21,421 | 130 | **340** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 13.71 |
| | 170 | **616** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 15.31 |
| 144°30,167 | 210 | **2679** | 0.00000 | 0.00016 | 0.00000 | 0.00010 | 17.17 |
| | 250 | **62720** | 0.00000 | 0.00016 | 0.00000 | 0.00028 | 15.76 |
| | 290 | **129459** | 0.00000 | 0.00015 | 0.00000 | 0.00044 | 20.02 |
| | 330 | **171799** | 0.00000 | 0.00018 | 0.00000 | 0.00053 | 19.46 |
| | 370 | **155259** | 0.00000 | 0.00013 | 0.00000 | 0.00064 | 20.29 |
| | 410 | **191903** | 0.00000 | 0.00005 | 0.00000 | 0.00070 | 20.15 |
| | 450 | **203431** | 0.00000 | 0.00006 | 0.00000 | 0.00083 | 20.70 |
| | 490 | **203463** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 14.45 |



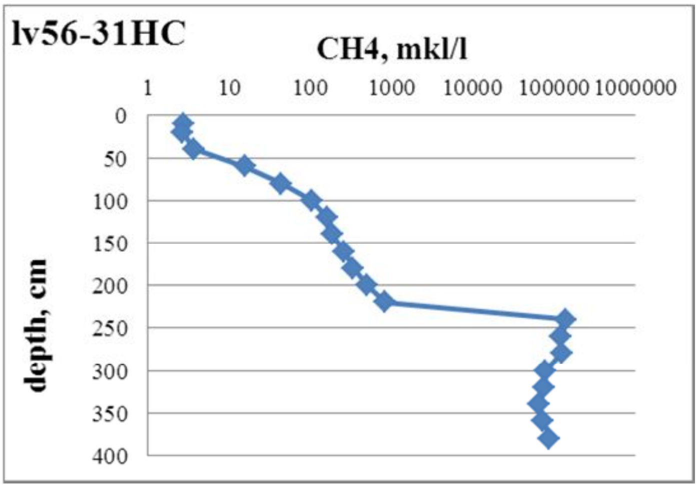
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-27HC | 10 | **23** | 0.00016 | 0.00008 | 0.00000 | 0.00000 | 11.06 |
| | 50 | **354** | 0.00007 | 0.00027 | 0.00000 | 0.00000 | 5.68 |
| | 70 | **364** | 0.00012 | 0.00026 | 0.00000 | 0.00012 | 6.33 |
| 53°21,937 | 90 | **218** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.70 |
| | 110 | **208** | 0.00005 | 0.00014 | 0.00000 | 0.00016 | 5.81 |
| 144°31,983 | 130 | **308** | 0.00000 | 0.00020 | 0.00000 | 0.00000 | 6.28 |
| | 170 | **243** | 0.00009 | 0.00016 | 0.00000 | 0.00000 | 5.47 |
| | 210 | **284** | 0.00008 | 0.00014 | 0.00000 | 0.00000 | 6.21 |
| | 250 | **411** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.12 |
| | 290 | **577** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.36 |
| | 310 | **712** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.83 |
| | 330 | **682** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.49 |
| | 350 | **719** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.44 |
| | 370 | **687** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.64 |
| | 390 | **717** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.73 |
| | 410 | **735** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.62 |
| | 430 | **726** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.86 |
| | 450 | **736** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.93 |
| | 470 | **619** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 4.96 |
| | 490 | **725** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.61 |
| | 510 | **723** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.20 |



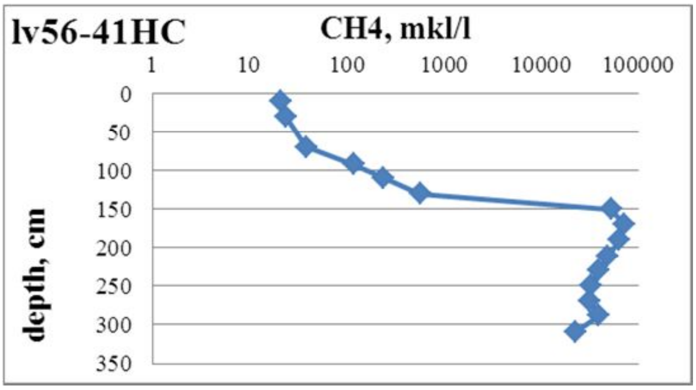
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-29HC | 40 | **15** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.12 |
| | 60 | **34** | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.30 |
| | 80 | **62** | 0.00007 | 0.00026 | 0.00000 | 0.00000 | 6.12 |
| 53°21,406 | 120 | **123** | 0.00004 | 0.00042 | 0.00000 | 0.00000 | 5.85 |
| | 160 | **178** | 0.00002 | 0.00063 | 0.00000 | 0.00000 | 7.07 |
| 144°30,169 | 200 | **201** | 0.00001 | 0.00068 | 0.00000 | 0.00000 | 7.54 |
| | 240 | **291** | 0.00002 | 0.00108 | 0.00000 | 0.00000 | 8.81 |
| | 280 | **416** | 0.00000 | 0.00158 | 0.00000 | 0.00000 | 10.34 |
| | 320 | **604** | 0.00000 | 0.00223 | 0.00000 | 0.00000 | 11.43 |
| | 360 | **1075** | 0.00000 | 0.00327 | 0.00000 | 0.00000 | 13.19 |
| | 400 | **1224** | 0.00002 | 0.00331 | 0.00000 | 0.00002 | 11.81 |
| | 440 | **1373** | 0.00000 | 0.00332 | 0.00000 | 0.00002 | 11.75 |
| | 480 | **1830** | 0.00000 | 0.00376 | 0.00000 | 0.00005 | 13.40 |
| | 515 | **2201** | 0.00000 | 0.00391 | 0.00000 | 0.00011 | 13.02 |
| | 552 | **1390** | 0.00000 | 0.00404 | 0.00000 | 0.00010 | 12.87 |



| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-31HC | 10 | **3** | 0.00007 | 0.00001 | 0.00000 | 0.00000 | 8.67 |
| | 20 | **3** | 0.00011 | 0.00008 | 0.00000 | 0.00001 | 7.13 |
| | 40 | **4** | 0.00010 | 0.00015 | 0.00000 | 0.00001 | 4.80 |
| 53°22,664 | 60 | **16** | 0.00004 | 0.00014 | 0.00000 | 0.00001 | 4.39 |
| | 80 | **44** | 0.00002 | 0.00039 | 0.00000 | 0.00000 | 4.65 |
| 144°25,420 | 100 | **104** | 0.00001 | 0.00109 | 0.00000 | 0.00000 | 3.27 |
| | 120 | **165** | 0.00000 | 0.00181 | 0.00000 | 0.00000 | 5.48 |
| | 140 | **188** | 0.00000 | 0.00235 | 0.00000 | 0.00000 | 3.49 |
| | 160 | **262** | 0.00000 | 0.00383 | 0.00000 | 0.00000 | 5.10 |
| | 180 | **341** | 0.00000 | 0.00505 | 0.00000 | 0.00000 | 5.14 |
| | 200 | **509** | 0.00000 | 0.00776 | 0.00000 | 0.00000 | 5.68 |
| | 220 | **846** | 0.00000 | 0.01103 | 0.00000 | 0.00002 | 6.88 |
| | 240 | **142485** | 0.00000 | 0.01866 | 0.00000 | 0.00201 | 6.12 |
| | 260 | **124523** | 0.00000 | 0.01574 | 0.00000 | 0.00151 | 5.77 |
| | 280 | **125367** | 0.00000 | 0.01588 | 0.00000 | 0.00199 | 5.26 |
| | 300 | **79676** | 0.00000 | 0.01138 | 0.00000 | 0.00127 | 5.00 |
| | 320 | **76438** | 0.00000 | 0.01098 | 0.00000 | 0.00160 | 4.85 |
| | 340 | **66708** | 0.00000 | 0.00983 | 0.00000 | 0.00142 | 4.87 |
| | 360 | **73893** | 0.00000 | 0.01084 | 0.00000 | 0.00151 | 5.07 |
| | 380 | **89830** | 0.00000 | 0.01244 | 0.00000 | 0.00178 | 5.75 |

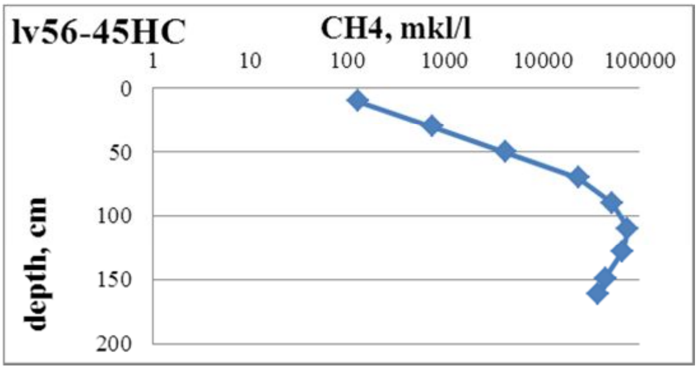


| | depth, cm | **CH4, mkl/l** | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-41HC | 10 | **21** | 0.00014 | 0.00025 | 0.00000 | 0.00014 | 3.56 |
| | 30 | **24** | 0.00000 | 0.00008 | 0.00000 | 0.00000 | 1.72 |
| | 70 | **38** | 0.00000 | 0.00007 | 0.00000 | 0.00000 | 1.59 |
| 53°30,958 | 92 | **117** | 0.00000 | 0.00152 | 0.00000 | 0.00000 | 2.01 |
| | 110 | **236** | 0.00000 | 0.00496 | 0.00000 | 0.00006 | 2.42 |
| 144°23,022 | 130 | **570** | 0.00000 | 0.01111 | 0.00000 | 0.00022 | 3.28 |
| | 150 | **52282** | 0.00000 | 0.02266 | 0.00000 | 0.00056 | 3.70 |
| | 170 | **71223** | 0.00000 | 0.02033 | 0.00000 | 0.00071 | 3.85 |
| | 190 | **63358** | 0.00000 | 0.01855 | 0.00000 | 0.00074 | 4.09 |
| | 211 | **48267** | 0.00000 | 0.01630 | 0.00000 | 0.00068 | 4.15 |
| | 230 | **38751** | 0.00000 | 0.01394 | 0.00000 | 0.00055 | 3.93 |
| | 250 | **32640** | 0.00000 | 0.01421 | 0.00000 | 0.00072 | 3.73 |
| | 270 | **31568** | 0.00000 | 0.01407 | 0.00000 | 0.00064 | 3.88 |
| | 288 | **38841** | 0.00000 | 0.01521 | 0.00000 | 0.00075 | 3.58 |
| | 309 | **22607** | 0.00000 | 0.01178 | 0.00000 | 0.00051 | 3.21 |



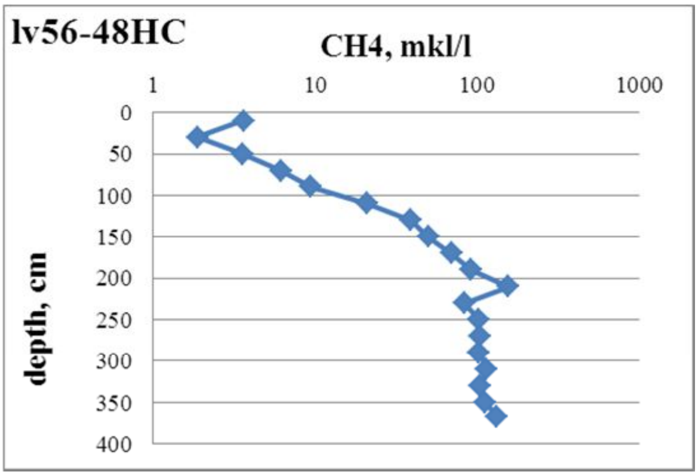
| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-44grab | | 151 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.81 |
| 47° 40,430 | | 340 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.32 |
| 144° 18,093 | | | | | | | |

| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-45HC | 10 | 129 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.95 |
| | 30 | 750 | 0.00000 | 0.00075 | 0.00000 | 0.00050 | 0.97 |
| | 50 | 4222 | 0.00000 | 0.00083 | 0.00000 | 0.00036 | 1.77 |
| 47° 40,405 | 70 | 23848 | 0.00000 | 0.00104 | 0.00000 | 0.00046 | 1.72 |
| | 90 | 52023 | 0.00000 | 0.00094 | 0.00000 | 0.00004 | 1.51 |
| 144° 18,099 | 110 | 76017 | 0.00000 | 0.00086 | 0.00000 | 0.00027 | 2.16 |
| | 128 | 67754 | 0.00000 | 0.00077 | 0.00000 | 0.00034 | 2.11 |
| | 149 | 45055 | 0.00000 | 0.00097 | 0.00000 | 0.00053 | 2.06 |
| | 161 | 37800 | 0.00000 | 0.00065 | 0.00000 | 0.00026 | 2.16 |




| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-46grab | 5 | 2 | 0.00013 | 0.00002 | 0.00001 | 0.00001 | 3.78 |
| 47° 41,333 | 10 | 9 | 0.00008 | 0.00001 | 0.00001 | 0.00001 | 3.70 |
| 144° 47,990 | 15 | 5 | 0.00007 | 0.00001 | 0.00001 | 0.00000 | 3.76 |

| | depth, cm | CH4, mkl/l | C2H4, nl/l | C2H6, nl/l | C3H6, nl/l | C3H8, nl/l | CO2, ml/l |
|---|---|---|---|---|---|---|---|
| lv56-48HC | 10 | **4** | 0.00005 | 0.00001 | 0.00001 | 0.00000 | 4.26 |
| | 30 | **2** | 0.00005 | 0.00001 | 0.00001 | 0.00000 | 3.19 |
| | 50 | **4** | 0.00006 | 0.00001 | 0.00000 | 0.00000 | 3.60 |
| 47° 37,137 | 70 | **6** | 0.00006 | 0.00002 | 0.00000 | 0.00000 | 3.43 |
| | 90 | **9** | 0.00005 | 0.00001 | 0.00000 | 0.00000 | 2.05 |
| 144° 45,650 | 110 | **21** | 0.00006 | 0.00009 | 0.00000 | 0.00000 | 2.30 |
| | 130 | **39** | 0.00005 | 0.00019 | 0.00000 | 0.00000 | 2.86 |
| | 150 | **50** | 0.00003 | 0.00023 | 0.00000 | 0.00000 | 3.45 |
| | 170 | **70** | 0.00003 | 0.00037 | 0.00000 | 0.00000 | 4.45 |
| | 190 | **93** | 0.00004 | 0.00053 | 0.00000 | 0.00000 | 3.78 |
| | 210 | **156** | 0.00000 | 0.00105 | 0.00000 | 0.00000 | 8.58 |
| | 230 | **83** | 0.00000 | 0.00078 | 0.00000 | 0.00000 | 3.02 |
| | 250 | **103** | 0.00000 | 0.00139 | 0.00000 | 0.00000 | 2.77 |
| | 270 | **104** | 0.00000 | 0.00157 | 0.00000 | 0.00000 | 3.41 |
| | 290 | **103** | 0.00000 | 0.00176 | 0.00000 | 0.00000 | 2.85 |
| | 310 | **115** | 0.00000 | 0.00234 | 0.00000 | 0.00000 | 3.48 |
| | 330 | **103** | 0.00000 | 0.00226 | 0.00000 | 0.00000 | 2.81 |
| | 350 | **113** | 0.00000 | 0.00292 | 0.00000 | 0.00000 | 2.12 |
| | 367 | **131** | 0.00000 | 0.00336 | 0.00000 | 0.00000 | 2.64 |



### 3.3.2. Gas Analysis (KIT)

*A. Hachikubo, Y. Soramoto*

In the LV-56 cruise we got dissolved gas in pore water (about 300 samples), hydrate-bound gas (6 samples), gas hydrate crystals and carbonates as shown in Table 3.3.2.1. The research target is molecular and isotopic compositions of hydrocarbons (from $C_1$ to $C_5$), $CO_2$ and $H_2S$, to estimate gas origin and to check isotopic fractionation between hydrate-bound and dissolved gases. Gas hydrate crystals provide information of cage occupancy and hydration number by a Raman spectroscopic analysis, and their thermal properties are obtained by a calorimetry. A carbon isotope ratio of authigenic carbonates relates with that of methane ascending from the deep layer of sediment.

Hydrate-bound gases were collected using a plastic syringe onboard the ship and stored in 5 mL vials sealed with butyl septum stoppers (Hachikubo *et al.*, 2010a; 2011). We placed each hydrate sample in a 50 mL plastic syringe, pushed the cylinder to reduce the dead volume, and attached the syringe to a vial using a needle. Another needle was attached to the vial to flush the air inside. Each vial was then filled with hydrate-bound gas devoid of sediment particles or pore water.

The dissolved gases in the pore water were extracted by a headspace gas method whereby 10 mL of sediment and a 10 mL saturated aqueous solution of NaCl were introduced into a 25 mL vial to create headspace. A 0.3 mL preservative (benzalkonium chloride (Waseda and Iwano, 2007), 50 wt% aqueous solution) was introduced into the 25 mL vial. The headspace was flushed by helium and the vials were then thoroughly shaken and stored overturned.

Gas hydrate crystals were stored in a dryshipper at the temperature of liquid nitrogen. Carbonate nodules were sampled in plastic bags.

Gas composition of hydrocarbons (from $C_1$ to $C_5$), $CO_2$ and $H_2S$ will be measured in KIT using a gas chromatograph (GC-14B, Shimadzu Corp.) equipped with thermal conductivity and flame ionization detectors coupled with a packed column (Sunpak-S, Shimadzu Corp.). The thermal conductivity detector (TCD) is to measure air components ($N_2$, $O_2$ and Ar: they are not separated), $CO_2$, $H_2S$ and high concentration of $C_1$. The flame ionization detector (FID) is to measure minor (low concentration) hydrocarbons because of its high sensitivity for $C_{2\text{-}5}$.

Carbon and hydrogen isotopes of hydrocarbons will be measured using a CF-IRMS (DELTA plus XP, Thermo Finnigan) employing a Carboxen-1006 PLOT capillary column (30 m × 0.32 mm I.D., Supelco). To avoid air contamination in low concentration cases of $C_1$, a Carboxen-1010 PLOT capillary column (30 m × 0.32 mm I.D., Supelco) were also used. The lower limit of determination in the case of $C_1$ $\delta^{13}C$ is 0.02% in the headspace gas. A backflush system of GC coupled with CF-IRMS enables us to resolve low concentrations of $C_2$ and $C_3$ (less than 0.1%) from $C_1$ and measure their isotopic composition.

Figure 3.3.2.1 shows the relation between the isotopic ratios and gas composition of hydrate-bound gas. These graphs are the same as the last cruise report of SSGH10 (Jin *et al.*, 2010), and the new data are plotted in the same field as those of the former cruises. Hydrate samples are retrieved at the No.5 area in the southern LVZ. The data of gas composition and $C_1$ $\delta^{13}C$ offshore Sakhalin Island showed their microbial gas origin (Bernard *et al.*, 1976) and $C_1$ $\delta^{13}C$ are smaller than that obtained from the northern LVZ (Hachikubo *et al.*, 2010a). The relationship between $\delta^{13}C$ of $C_1$ showed that not only $C_1$ but also $C_2$ is rather microbial. Hydrate-bound microbial $C_2$ was reported by Sassen and Curiale (2006) and Hachikubo *et al.* (2010b). Although hydrate-bound $C_2$ may change the crystallographic structure, $C_2$ composition seems too small (less than 0.1 mol% of the total hydrocarbon gases) and the hydrate crystal is estimated as the crystallographic structure I.

## References


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Table 3.3.2.1 Sample list for gas analyses.

| Date | Core | Hydrate-bound gas | Dissolved gas in pore water | | Hydrate | Carbonate for isotope |
|---|---|---|---|---|---|---|
| | | | | for check | | δ13C of CO2 |
| | | 5mL vial | 25mL vial | 25mL vial | 20mL plastic bottle | plastic bag |
| 2011/8/16 | LV56-01HC | | 10 | 1 | | |
| 2011/8/16 | LV56-03HC | 6 | 16 | | 3 | 2 |
| 2011/8/16 | LV56-05HC | | 18 | | | 1 |
| 2011/8/16 | LV56-07HC | | 11 | 3 | | 1 |
| 2011/8/18 | LV56-11HC | | 24 | 3 | | |
| 2011/8/18 | LV56-13HC | | 18 | 1 | | |
| 2011/8/18 | LV56-15HC | | 19 | | | |
| 2011/8/18 | LV56-17HC | | 11 | | | |
| 2011/8/19 | LV56-19HC | | 25 | | | 1 |
| 2011/8/19 | LV56-21HC | | 22 | | | |
| 2011/8/19 | LV56-23HC | | 15 | 3 | | 1 |
| 2011/8/20 | LV56-25HC | | 26 | | | 1 |
| 2011/8/20 | LV56-27HC | | 26 | | | |
| 2011/8/20 | LV56-29HC | | 14 | | | |
| 2011/8/20 | LV56-31HC | | 21 | | | 1 |
| 2011/8/21 | LV56-41HC | | 16 | | | 2 |
| 2011/8/24 | LV56-42GR | | 1 | | | |
| 2011/8/24 | LV56-44GR | | 1 | | | 1 |
| 2011/8/24 | LV56-45HC | | 8 | | | 1 |
| 2011/8/24 | LV56-46GR | | 1 | | | |
| 2011/8/24 | LV56-48HC | | 19 | | | 1 |
| | total | 6 | 322 | 11 | 3 | 13 |

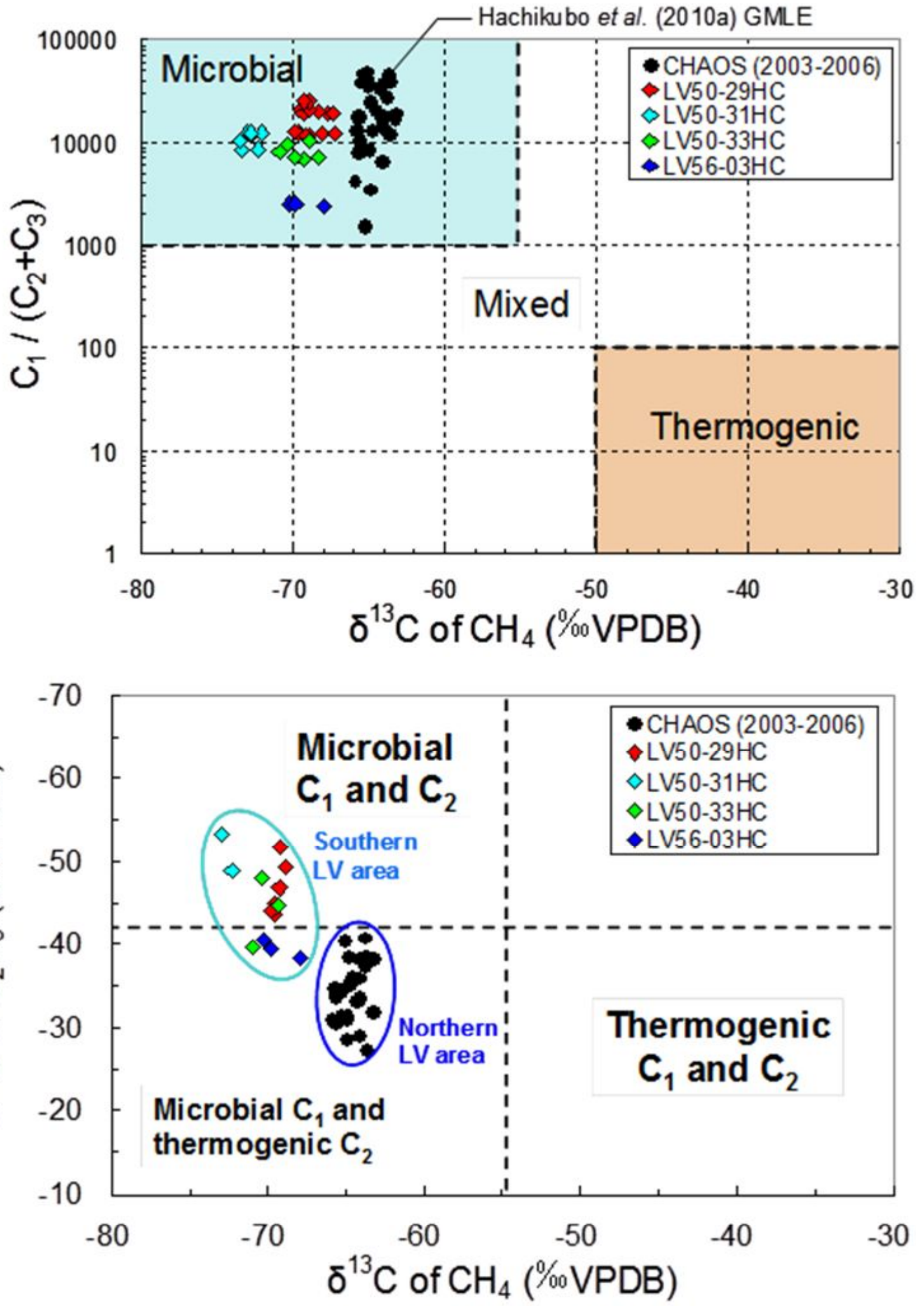



Fig. 3.3.2.1. Relation between molecular and isotopic compositions. upper: $C_1$ $\delta^{13}C$ and the ratio $C_1/(C_2+C_3)$. lower: $\delta^{13}C$ of $C_1$ and $C_2$. The gas origin fields are in accordance with Bernard *et al.* (1976), Taylor *et al.* (2000), and Milkov (2005). Data of CHAOS project (2003-2006) are shown in Hachikubo *et al.* (2010a), and those of SSGH10 (LV50 cruise) are shown in Jin *et al.* (2010). The data of LV56-03HC are the new data of SSGH11.

### 3.3.3. Pore Water Analysis (KIT)

*H. Minami, Y. Soramoto*

3.3.3.1. Pore water sampling

The pore-water sampling was conducted on board by using squeezers designed and constructed at Kitami Institute of Technology. A 10 cm portion of the sediment core at every 10 to 40 cm depth interval was taken into a zippered plastic bag and was kept in a refrigerator in the Research Vessel until squeezing process was started (usually not more than half day). The sediment sample in the zippered plastic bag was taken into the squeezer, and pore water sample was directly collected into a plastic syringe equipped with a plastic filter cartridge containing a polytetrafluoroethylene membrane filter (pore size 0.2 μm). The pore water samples were filtrated by passing through the membrane filter and were collected into a polyethylene bottle. The pore water samples were kept under chilled temperature (refrigerator in the Research Vessel) during the cruise.

3.3.3.2. Water samples to be measured

The water samples obtained during in this cruise are 340 samples including (i) pore water samples, (ii) bottom seawater samples, and (iii) gas hydrate water samples.

The bottom seawater samples were obtained by the CTD Niskin sampler. The bottom seawater from top of the hydro corer was also sampled. The gas hydrate water samples were obtained by the dissociation of gas hydrate samples. All water samples were filtrated by the 0.2 μm PTFE membrane filters and were kept under chilled temperature.

The core name and the sampling interval are as follows:

| Core name | Sampling interval | Number of samples (incl. seawater from corer) |
|---|---|---|
| LV56-01HC | every 40 cm | 11 |
| LV56-03HC | every 10 cm | 26 |
| LV56-05HC | every 20 cm | 19 |
| LV56-07HC | every 20 cm | 12 |
| LV56-11HC | every 20 cm | 25 |
| LV56-13HC | every 20 cm | 18 |
| LV56-15HC | every 20 cm | 19 |
| LV56-17HC | every 40 cm | 11 |
| LV56-19HC | every 40 cm | 13 |
| LV56-21HC | every 20 - 40 cm | 14 |

| | | |
|---|---|---|
| LV56-23HC | every 20 cm | 14 |
| LV56-25HC | every 20 - 40 cm | 22 |
| LV56-27HC | every 20 cm | 28 |
| LV56-29HC | every 20 - 40 cm | 23 |
| LV56-31HC | every 20 cm | 20 |
| LV56-41HC | every 10 - 20 cm | 20 |

3.3.3.3. Chemical analyses of pore water

The determination of the concentrations of sulfate ion, chloride ion, hydrogen carbonate ion, calcium, potassium, sodium and magnesium in the pore- and seawater samples will be carried out at Kitami Institute of Technology, Japan. The concentrations of anions will be determined by ion chromatography. The concentrations of sodium and magnesium will be determined by inductively coupled plasma atomic emission spectrometry. The concentrations of potassium and calcium will be determined by flame atomic absorption spectrometry.

Stable isotope ratios of oxygen and hydrogen of the pore- and seawater samples will be analyzed by mass spectrometry. The results of the isotopic measurements of the water samples will be presented in per-mil delta notations ($\delta^{18}O$ and $\delta D$) relatively to Vienna Standard Mean Ocean Water (VSMOW) and Standard Light Antarctic Precipitation (SLAP) issued from International Atomic Energy Agency (IAEA).

The pH values of the water samples described above were measured on board using a pH meter just after obtaining the water samples.

### 3.3.4. Sediment Analysis (KIT)

*S. Yamashita, H. Dewa*

To examine the soil properties of sea-bottom sediments and to evaluate the effect of the vaporization of dissolved gas in the pore water on the strength properties, two kinds of on-board tests were performed for the samples retrieved by a gravity corer. Additionally, the concentrations of dissolved gas in the pore water will be measured.

*On-board Tests*

To measure the strength of sediments immediately after recovery, the following two kinds of tests were performed onboard.

a) Vane shear test

The test was conducted by using shear vanes of 10 mm in diameter, D, and 20 mm in height, H, attached to a compact torque driver. The vane shear test was conducted at 20 to 40 cm intervals on the longitudinally cut core surface (see photo 3.3.4.1.). The maximum torque, *M*, is measured by rotating the torque driver while penetrating the vane in the core. The vane shear strength, $\tau_v$, is calculated from the following equation.

$$\tau_v = \frac{M}{\pi(\frac{D^2 H}{2} + \frac{D^3}{6})}$$

b) Cone penetration test

The device used is a force gage type compact cone penetration meter (see photo 3.3.4.2.). The diameter, length, and apex angle of the cone are 9mm, 18mm, and 30 degrees. As for the vane shear test, the cone meter was applied to the longitudinally cut core surface at 20 to 40 cm intervals to measure the penetration load, *p*. The cone penetration resistance, $q_c$, is obtained using the following equation.

$$q_c = \frac{p}{A}$$ (A: the sectional area of the cone)

Photo 3.3.4.1. Vane shear test

Photo 3.3.4.2. Cone penetration test

*Sub-sampling*

For measurement of the water content, 20 to 40 cm interval samples (total 239) were taken. About 10 mL sediment was sampled from the sediment core using a syringe (10mL size) and put into a 20 mL vial bottle.

*Test results*

The following figures show the typical vane and cone penetration test results.

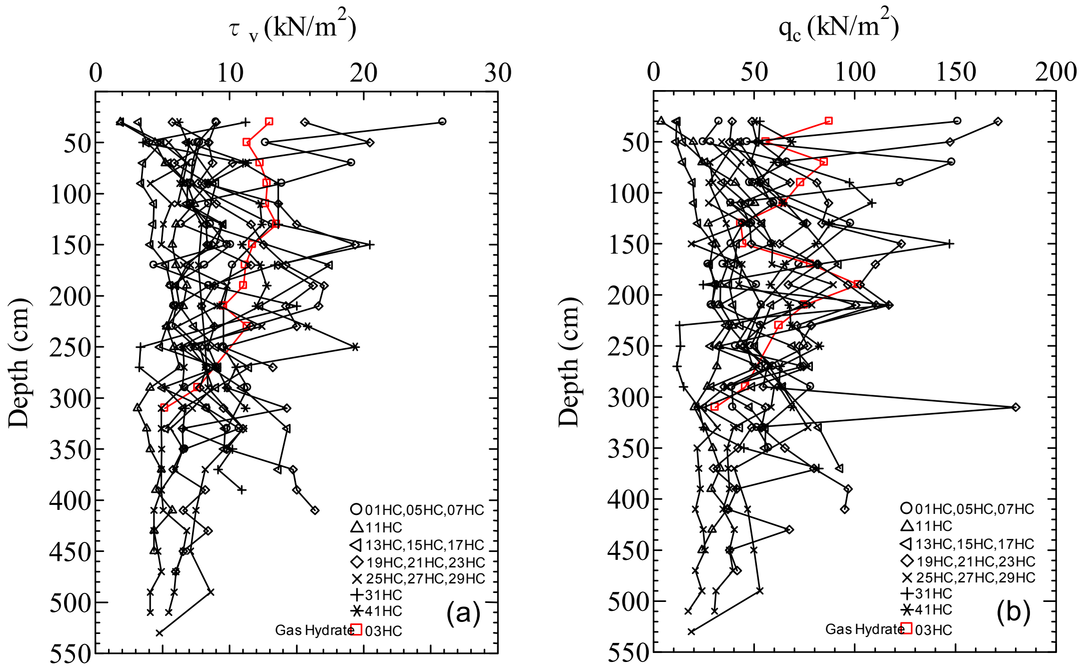



Fig. 3.3.4.1. Typical onboard test results; (a) vane shear test, (b) cone penetration test

## 3.3.5. Sediment Analysis (POI)

*A. Derkachev, N. Nikolaeva*

***Method***

One type of corer was prepared for sediment sampling: hydro-corer (HC) by diameter of 138 mm (Fig. 3.3.5.1). Their length was 575 cm. To rapidly extract sediment column from the corer, special flexible plastic 2-sectional liners were used with diameter of 125 mm.

After rising of a hydrocorer on the deck, liners with sediment were moved in the laboratory, and sediment was cut up on two parts for subsequent operational processing. Time interval from rise corer on the deck up to cutting of sediment in laboratory amounted 10 minutes. Following sedimentological study of the sediment cores was realized with the use of standard scheme including description of structure, texture, color, density, inclusions (concretions, shells, dropstone), as well as gas-hydrates and character of contacts between layers. Smear slides were made for continued investigation under microscope with the aim of preliminary determination of sediment components.

Fig.3.3.5.1. Hydrocorer.

***Sedimentological features of study areas***

During 56-th cruise of R/V "Akademik M.A. Lavrentyev" sediment coring was carried out within two areas: southern part of area № 1 and western part of area № 3 (Terpeniya Bay). 18 sediment cores and 3 grabs (one of them has brought nothing) were taken totally (Fig. 3.3.5.2). Two cores have recovered gas hydrates; 9 cores contained carbonate concretions of different size, shape and density; two cores have brought specific authigenic mineral called glendonite ("gennoyshi") and two cores were estimated as background. Recovered sediments have mainly Holocene-Late Pleistocene age.

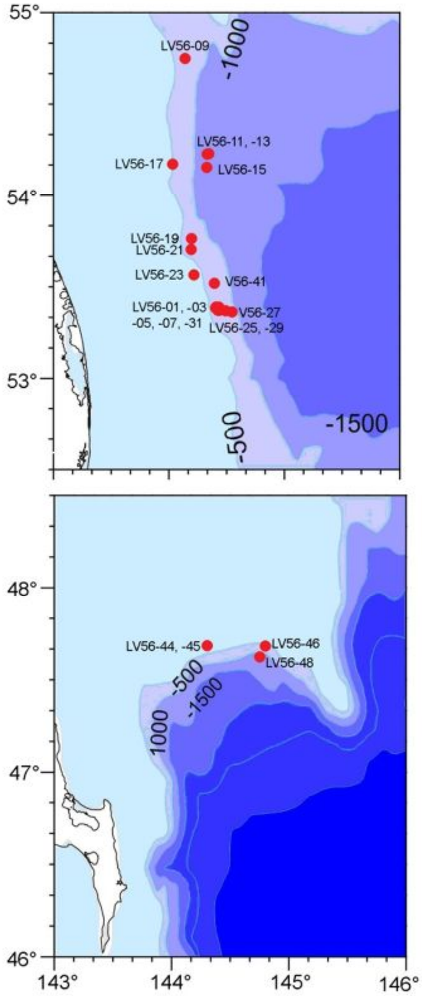



Fig. 3.3.5.2. The location of sediment sampling stations.

***SLF area***

9 sediment cores with maximum recovery of 573 cm were raised on the water depth of 613-785 m. One core was taken as a background for KOPRI (LV56-41HC). Sometimes under lifting of hydrocorer with gas saturated sediments on the shipboard a lot of gas bubbles were visible in the water column (Fig.3.3.5.3).

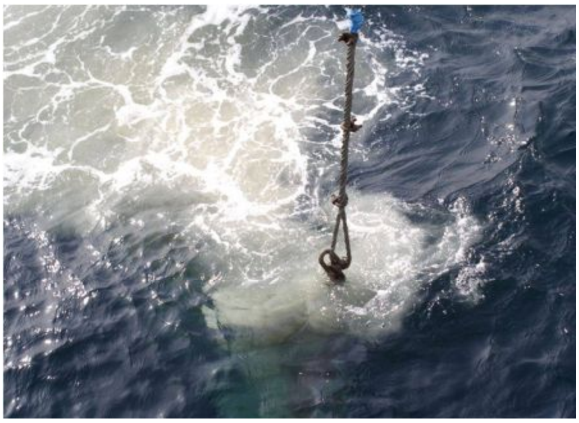


Fig. 3.3.5.3. Methane outflow during lifting of hydrocorer with sediments.

***Area southwards from canyon***

One sediment core was taken in this area on the water depth of 740 m. It was station LV56-09HC. Only small amount of coarse-grained gravel-pebble deposits with sorted sand were found in the corer catcher. This testifies that modern sedimentation is absent in this place of slope.

***NLF Area***

This area is located on the junction of the Lavrentyev Fault and fault perpendicular to it. Three sediment cores with the maximum recovery of 480 cm were taken here on the water depth of 430-665 m. Two of them have recovered typical for seepage areas gas saturated section with carbonate concretions and shell fragments. Another one has brought sediments of almost black colour enriched with hydrotroilite.

***Terpeniya Bay***

This area is located close to Terpeniya Cape. The main aim was to find indicators of gas hydrate or methane seepage presence.

Two sites located in western and eastern parts near flare areas close to shelf break, were sampled. Two stations (one core and one grab) were made on western site and two stations (one core and one grab) – on eastern site.

The length of raised cores averaged 173 and 383 cm. Mainly Late Pleistocene deposits were recovered. Some horizons of them are enriched with sorted turbidite sands.

Grabs have brought very coarse-grained sediments by the thicknesses of 10 and 20 cm represented of sands with a lot of gravel and pebble. Some flat rough crusts were found in one of them (LV56-44GR). These crusts consist of very dense sediment impregnated by iron hydroxides (limonite). Layer of hydrotroilite by thickness of 3 cm is marked at the subbottom depth of about 10 cm; inside of it Calyptogena shell was found.

Both silty sands with a lot of pebble and gravel (LV56-44GR) and clayey silt (silty clay) with numerous sandy turbidite interlayers (LV56-45HC) were raised within western site. The slice of clayey-silty deposits containing a lot of coarse-grained fraction represented of mixture from silt, sand, pebble and gravel (LV56-46GR, LV56-48HC) was recovered to the east.

***Carbonate precipitates***

Carbonate precipitates of different size, shape and density were discovered in 9 sediment cores. Upper boundary of their occurence located from near-surface horizon (station LV56-45HC) up to depth of 480 cm (station LV56-25HC). Two types of them were found: methane-related and diagenetic. They occur in both Holocene and Late Pleistocene deposits.

Methane-derived carbonate precipitates have different size, shape and density varying from small soft spots and lenses up to large dense concretions and crusts. The few types of them were found within study areas:

1) soft (or crumbly) light green precipitates representing the initial stage of carbonate formation (Fig. 3.3.5.4 a);

2) dense rough concretions with numerous small acute or smoothed cusps, concretions of irregular or angular shape - all of them have complicated structure: hard nuclear and brittle crumbling outer part of light green colour consisting of sediment pierced by carbonate; some concretions contain inclusions of small shells and their fragments as well gravel (Fig. 3.3.5.4 b);

3) concretions of ideal round shape (like ball) (Fig. 3.3.5.4 c);

4) hard carbonate crusts, often they grow on the pebble or mollusk shells (Fig. 3.3.5.4 d).

Unusual diagenetic carbonates were discovered on stations LV56-01HC and LV56-21HC. Aggregates composed by glendonite crystals (so-called “gennoyshi”) are diagenetic carbonate. They were discovered in Late Pleistocene deposits. Their colour was reddish-brown, yellowish-brown, and they were represented of grown together pyramidal calcite crystals which formed bipyramidal and rosette-like aggregates (Fig. 3.3.5.4 e). As it is known, glendonite represents pseudomorphs on metastable ikaite mineral ($CaCO_3 \cdot 6\ H_2O$). Ikaite is formed inside sediments enriched by organic matter and under low temperatures (about $0^oC$) of near-bottom waters that is a good paleoceanological feature.

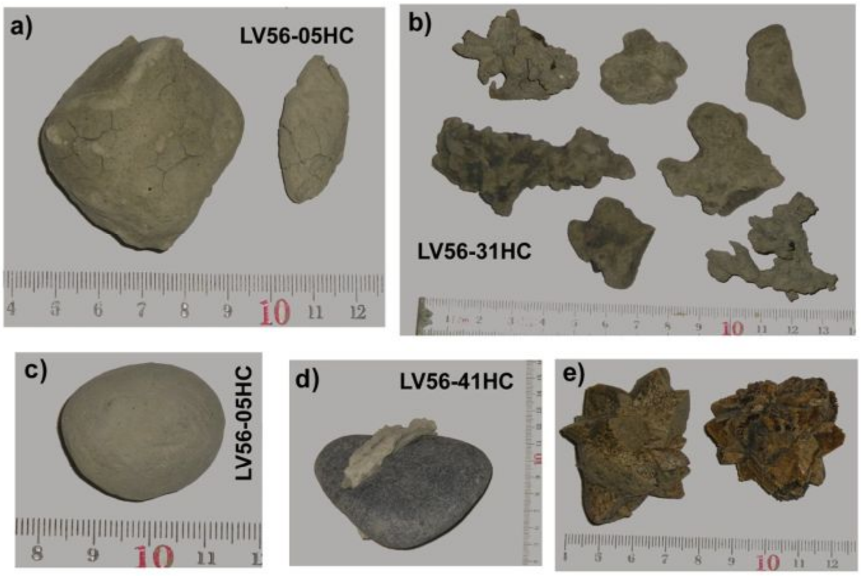



Fig. 3.3.5.4. Types of carbonate precipitates.

The large thick-walled *Calyptogena* shell covered powerful very hard carbonate crust of gray color with internal and from outer side, has been found in Late Pleistocene deposits of station LV56-31HC. Its size reached 15 cm. Under injection of hydrocorer in deposits shell has been broken on some large fragments (Fig. 3.3.5.5)

Fig.3.3.5.5. Fragments of Calyptogena shell covered by carbonate crust.

***Gas hydrates***

Only two sediment cores contained gas hydrates. One of them (LV56-03HC) has brought their pieces and interlayers on the subbottom depth of 244-335 cm (Fig. 3.3.5.6), and another one (LV56-31HC) contained presumably cryptocrystalline gas hydrates within interval of 220-310 cm.

Some indicators testified about it: 1) well visible sinuous boundary between dense homogeneous clayey silt and very soft water saturated sediment (Fig. 3.3.5.7); 2) within this interval here and there sediment was heaved probably because of decomposition of gas hydrates microcrystals, and its water saturation increased before our eyes; 3) under pressing on sediment small bubbles and drops of water appeared, and slight cracking was heard (Fig. 3.3.5.8).

Fi6. 3.3.5.6. Lenses of gas hydrates in the core LV56-03HC.

Fig. 3.3.5.7. Sinuous boundary between dense and water saturated sediments.

Fig. 3.3.5.8. Sediment cracking under decomposition of gas hydrates microcrystals.

***Results***

Sedimentary section of studied areas has been described in detail in reports of previous cruises *(Derkachev, Nikolaeva, 2010; Nikolaeva et al., 2011*). As investigations were carried out on the same part of the Sakhalin slope, as earlier, any new features of a sedimentary section were not revealed. This testifies that sediment composition within all NE Sakhalin slope is constant. All described earlier lithological slices characteristic for this region, were recovered: clay-diatomaceous, clay homogeneous, clay with the traces of sediment heave due to gas expansion and clay gas-saturated with pseudobrecciated texture.

1. Sedimentary section within area № 1 has all evidences of methane emanations influence on sediment composition. The presence of methane-derived carbonate concretions, fragments of chemoautotrophic mollusk fauna (for example, *Calyptogena*), gas-saturated sediments with specific pseudobrecciated texture, layers and lenses of gas hydrates testify about it.

2. Glendonite crystals discovered at some stations, testify about existence of unusual conditions during some periods of sediment formation (both sediment enrichment by organic matter and low temperature of near-bottom waters).

3. Seismic profiles carried out in area № 3 (Terpeniya Bay) have showed the absence of gas hydrates. But the presence of gas flares, carbonate precipitates and specific mollusk fauna testify about ambiguous situation in this area. On our opinion, it is necessary to expand study area in the western direction.

***Reference***

*1. Derkachev A.N., Nikolaeva N.A.* Sediment analysis // Operation Report of Sakhalin Slope Gas Hydrate Project 2009, R/V Akademik M. A. Lavrentyev Cruise 47, New Energy Resources Research Center, Kitami Institute of Technology, Kitami. Eds. H. Shoji, Y. K. Jin, A. Obzhirov and B. Baranov, 2010, p. 79-86.

*2. Nikolaeva N., Derkachev A., Jin Y.K., Krylov A., Obzhirov A. and Yamashita S. Sediment lithology. Sea of Okhotsk* // Gas Hydrate Studies in Okhotsk Sea and Lake Baikal. Eds. H. Shoji and Y.K. Jin. Kitami, Japan, 2011. P. 152-162.

## 3.3.6. Paleoceanological Analysis (KOPRI)

*Y. K. Jin*、*J. K. Hong*

It is well known that the sedimentation rates on the Sakhalin slope are remarkably high (Cruise Report, 1999, 2003; Gorbarenko et al., 2002), which allows us to get high resolution records of the climate, surface water conditions, sea-ice cover and varying productivity. The goals of this investigation are the influence of Amur River on the paleoceanography and sedimentation in the Okhotsk Sea during the Late Pleistocene – Holocene.

According to previous studies (Operation Report of SSGH Project, 2010), three lithological units are clear expressed on matter composition: clay-diatomaceous (U1), clay with admixture of diatoms (U2) and clay homogeneous (U3). The boundary of t Early Holocene (U2) and Late Pleistocene (U3) deposits is marked on the subbottom depth from 50 up to 350 cm (stations LV50-33HC and LV50-01HC accordingly) in the southern area of Lavrentyev Fault.

For paleoceanological study, Core LV56-41HC was taken at the continental slope (53° 30.958'N 144°23.022'E) from a depth of 650 m (Fig. 3.3.6.1; Table 3.3.6.1). The recovery length of sediments is 330 cm. We used hydro-corer (HC) with the diameter of 138 cm and the length 550 cm for coring.

After two time trials at other sites, we took a good core containing Holocene and Pleistocene sediments together nearby Station LV 50-33HC. Although changes in color and lithology of the sediments in Core LV56-41HC are apparently not distinct, we expect that the boundary of Holocene (U2) and Pleistocene (U3) occurs at ca. 120-130 cm.

Sampling procedure is as follows :

1. Sediment recovery was performed with hydro-corer (HC) : Max. length 550 cm with the diameter of 138 cm.
2. Sediment core was splitted. One half was used for description, geochemical analysis (gas and pore water), the other half was sampled for paleoceanlogical analysis.
3. Sediments in the half core were sliced by 1 cm-interval using spatula.
4. Each 1 cm-thick sediment slice was sampled and stored in a sealable vinyl bag.
5. All vinyl bags were packed in plastic boxes for shipping to KOPRI

Sampling was done by Young Keun Jin and Jong Kuk Hong in the wet lab of R/V Akademik

M.A. Lavrentyev. Actual analysis will be conducted at KOPRI after delivery.

Table 3.3.6.1 Information on the core for paleoceanological analysis

| Coring No. | Location (Lat. / Lon.) | Water Depth (m) | Date (LT) | Recovery Length (cm) | Sampled range (cmbsf*) |
|---|---|---|---|---|---|
| LV50-35HC | 53° 30.958'N 144°23.022'E | 650 | Aug. 21 08:40 | 330 | 3-330 |

* cm below the seafloor when assuming that the top of a core is coincident with the seafloor

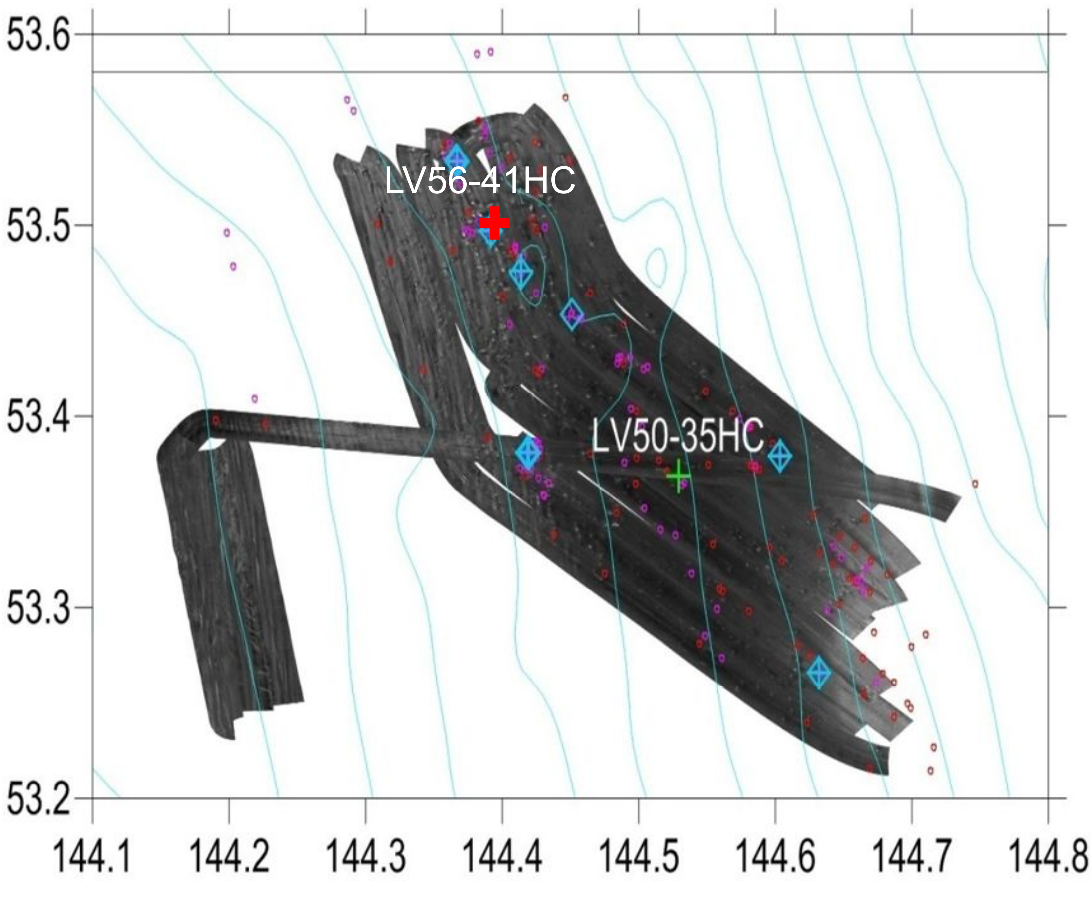



Fig. 3.3.6.1. Location of LV56-41HC (red cross) and LV50-35HC (green cross) that was obtained in SSGH-11 cruise for paleoceanological analysis.

## 3.4. CTD Operation and Analyses

### 3.4.1. Hydrological Researches

*A. Karnaukhov, V. Bannov*

### Devices and technique of supervision

Oceanological investigations in 56th cruise of R/V "Akademik M.A. Lavrentyev" were carried out with the use of CTD probe "SBE 9plus" (Fig. 3.4.1.1). Water sampling was spent by means of 12-item Rosette plastic bottles «Niskin» by volume of 5 l on 12 set horizons (Fig. 3.4.1.2). Sampling horizons got out in depend on concrete conditions and depth of a place. All investigations were carried out from sea surface to the bottom.


Fig. 3.4.1.1. CTD probe "SBE 19plus".

Fig. 3.4.1.2. CTD probe in the complete set with Rosette.

The basic difference of the CTD probe of Sea Bird Electronics consists that the main gauges are in the separate chamber with compulsory prorolling of water with constant speed. In this case, two chambers are established on the device. Such configuration excludes "sticking" of a capillary film; it raises stability of work of sensor control cleaning casual noise. The basic characteristics of gauges are resulted in the Table 3.4.1.1.

Table 3.4.1.1 Basic characteristics of gauges

| | Temperature (°C) | Conductivity (S/m) | Pressure | A/D Inputs |
|---|---|---|---|---|
| **Measurement Range** | -5 to +35 | 0 to 7 | 0 to full scale range (in meters of deployment depth capability): 1400 / 2000 / 4200 / 6800 / 10500 meters | 0 to +5 volts |
| **Initial Accuracy** | 0.001 | 0.0003 | 0.015% of full scale range | 0.005 volts |
| **Typical Stability** | 0.0002/month | 0.0003/month | 0.018% of full scale range/year | 0.001 volts/month |
| **Resolution at 24 Hz** | 0.0002 | 0.00004 | 0.001% of full scale range | 0.0012 volts |
| **Sensor Calibration** (measurement outside these ranges may be at slightly reduced accuracy due to extrapolation errors) | -1.4 to +32.5 | 2.6 to 6 S/m, plus zero conductivity (air) | Paroscientific calibration, plus Sea-Bird temperature correction | - |
| **Time Response** (single pole approximation including sensor and acquisition system contributions) | 0.065 seconds | 0.065 seconds | 0.015 seconds | 5.5 Hz 2-pole Butterworth Low Pass Filter |
| **Master Clock Error Contribution** (Based on 5-year worst-case error budget, including ambient temperature influence of 1 ppm total over -20 to +70 °C plus 1 ppm first year drift plus 4 additional year's drift at 0.3 ppm/year) | 0.00016 °C | 0.00005 S/m | 0.3 dbar with 6800 m (10,000 psia) pressure sensor | - |
| **Auxiliary Voltage Sensors** | Power available for auxiliary sensors: 1 amp at +14.3 volts | | | |
| **Seacable Inner Conductor Resistance** | 350 ohms or less | | | |
| **Main Housing Material** | Up to 6800 meter (22,300 ft) - aluminum<br>Up to 10500 meter (34,400 ft) - titanium | | | |
| **Weight** (including all standard sensors and cage) | With aluminum main housing -<br>*In air* 25 kg (55 lbs) *In water* 16 kg (35 lbs)<br>With titanium main housing -<br>*In air* 29 kg (65 lbs) *In water* 20 kg (45 lbs) | | | |

There are two ways for the fastening of a probe to both the protection and the block of management of bathometer closing (Rosette): vertical and horizontal. The horizontal way (Fig. 3.4.1.3) is applied in this case. At such fastening design, height in gathering less and it is more convenient to deduce the device out a board through splashboard, not opening "gate". However, the twisting moment twisting in this case increases.

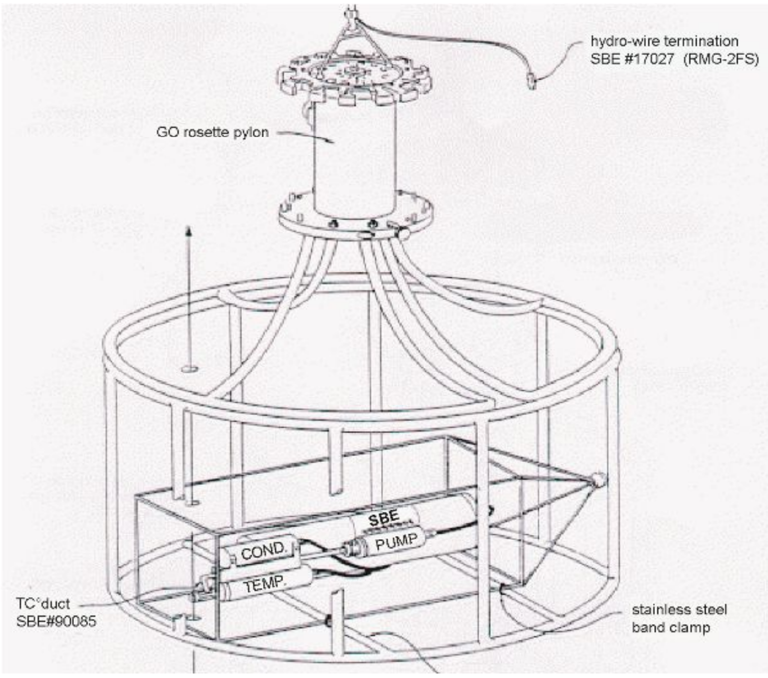



Fig. 3.4.1.3. Fastening of a probe to the protection.

Besides sounding and sampling, continuous measurements of temperature and salinity for the subsurface water layer were carried out during cruise by use of thermosolinograf SBE 45. Their primary goal was detection of frontal zones and vortical formations. Its technical characteristic is listed in the Table 3.4.1.2.

Table 3.4.1.2 Technical characteristics of thermosolinograf SBE 45

| | Temperature (°C) | Conductivity (S /m) | Salinity (PSU) |
|---|---|---|---|
| Ambit of measuring | -5-35 | 0-7<br>(0-70 mS/cm) | 0-35 |
| Accuracy | 0.002 | 0.0003<br>(0.003 mS/cm) | 0.003 |
| Resolution | 0.0001 | 0.00001<br>(0.0001 mS/cm) | 0.0002 |
| Stability<br>For 1 month | 0.0002 | 0.0003<br>(0.003 mS/cm) | 0.003 |

The water sampling was carried out from the valve located in the bottom of a ship on fixed depth of 4 meters from a waterline. Registration with step-type behaviour of 10 сек was made on the computer located in the hydrological laboratory. Position of a ship in sea space was continuously fixed by means of the GPS-navigator.

## Preliminary results of researches

Twenty seven hydrological stations were made during the cruise. Vertical profiles of distribution for temperature, salinity, dissolved oxygen, turbidity and fluorescence of seawater from a surface to the bottom are obtained. The first 24 stations are located on a slope of the western sector of the Deryugin Basin, last three - on the south of the Terpeniya Bay (Fig. 3.4.1.4). During transit of ship measurements of temperature and salinity were continuously conducted (Fig. 3.4.1.5).

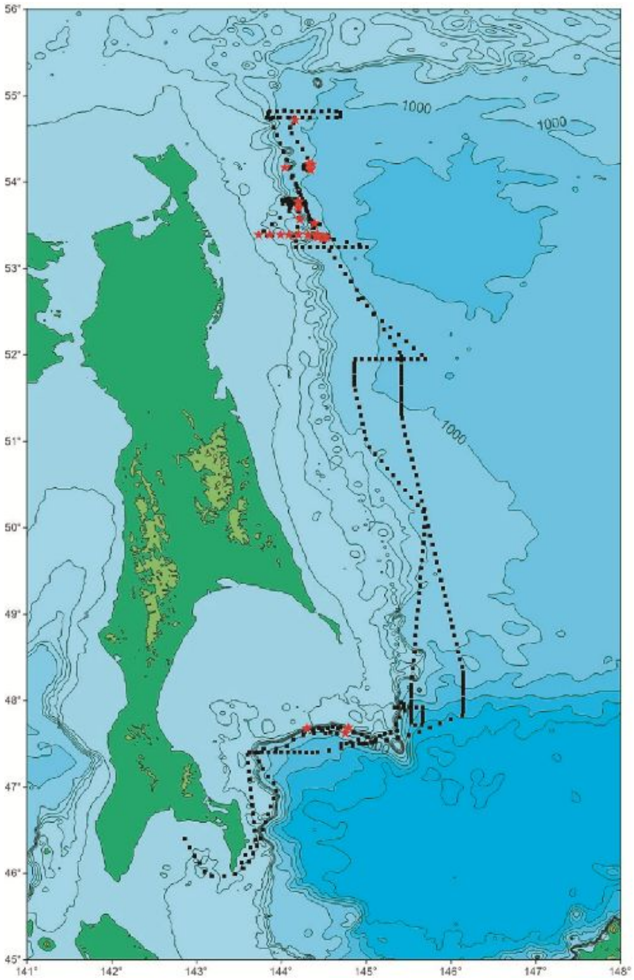



Fig. 3.4.1.4. Scheme of location of CTD stations (red asterisks) and superficial measurements of temperature and salinity along a ship route (dotted lines).

As it is seen in Fig. 3.4.1.5, surface temperature along the route of the ship has zonal latitudinal character. Its minimum values (9.5°C) are marked in a northwestern part of the Deryugin Basin, maximum (up to 17°C) ones were measured within the south of the Terpeniya Bay. Salinity increases in a southern direction; the maximum values (32.3 psu) are positioned to the north from the Kuril Basin. These water masses represent typical Okhotsk-sea type, which not affected by East Sakhalin current. Lower values of salinity (31 psu) are located to the south from the Terpeniya Bay. Desalination of water in this area can be attributed to the influence of the above mentioned current. Character of distribution of temperature and salinity has remained and later 10 days, that is registered on a route back in Korsakov. This fact testifies about low dynamic activity within investigated areas at the time of work.

It is necessary mark a local minimum of temperature on a traverse of Aniva Cape, which is accompanied by local increase in salinity (11°C, 31.5 psu). This phenomenon is due to cyclonic vorticity, which is characteristic for the dynamics of water near the capes. It should be added, that in Aniva Bay, apparently, quasi-stationary cyclonic eddy is located; it was observed in the previous expeditions of R/V ”Akademik M.A. Lavrentyev”.

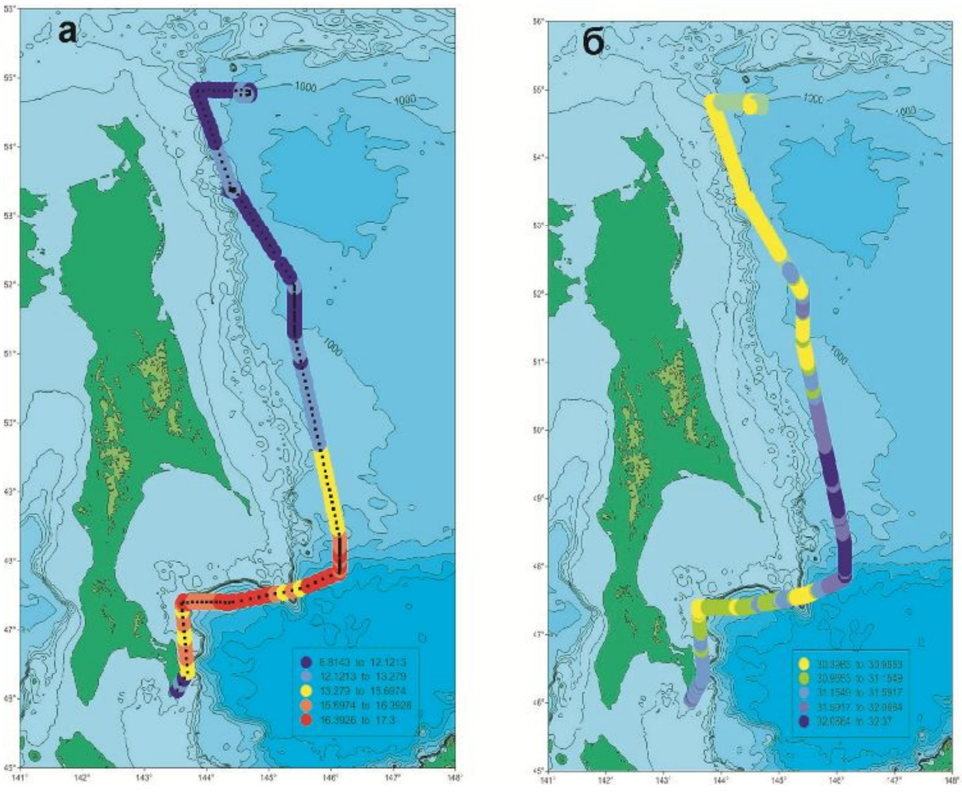



Fig. 3.4.1.5. Distribution of superficial temperature (a) and salinity (b) along a ship route.

Analyzing the results of hydrological soundings, it is possible to settle out three types of vertical profiles for temperature and dissolved oxygen, which are presented in Fig. 3.4.1.6.

Profile of the first type is located in the seaward part of study area, and it is characterized by one cold subsurface layer (CSL), whose nuclear (-1.11°C) is on the horizon of 95 m. Profile of the second type is on a slope, and it is presented by more powerful cold layer with several extrema. Its thickness makes 300 m; the upper minimum (-1.32°C) is located on horizon of 162 m, lower one (-1.06°C) - on horizon of 300 m. The third type of a vertical profile is situated on a slope more close to a shelf, and it is characterized by less developed cold intermediate layer (-0.52°C) on horizon of 220 m.

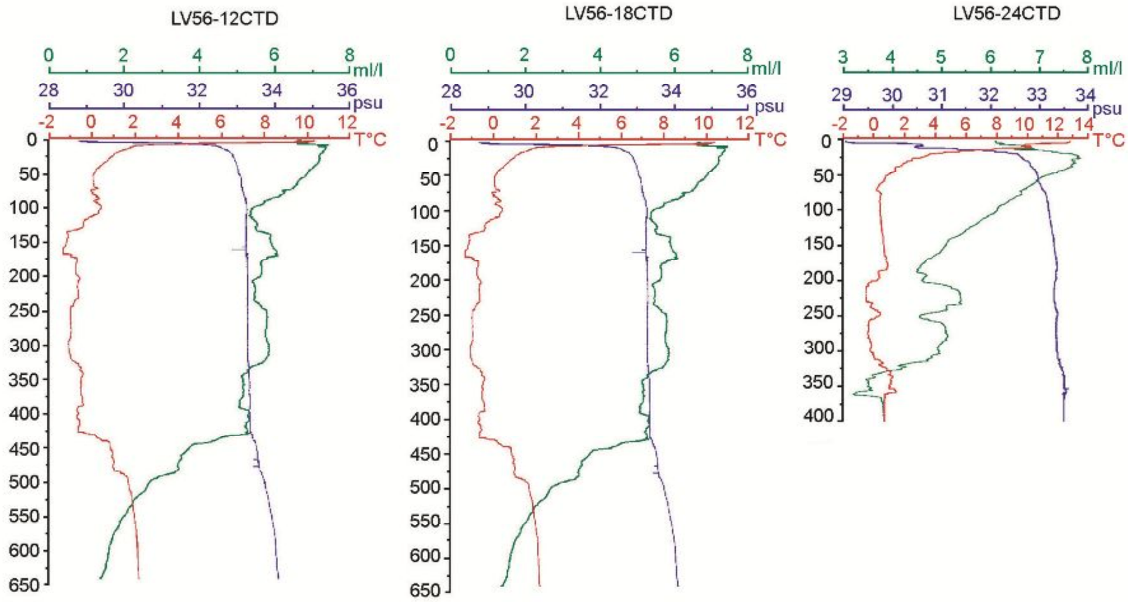



Fig. 3.4.1.6. Vertical profiles of temperature (red), salinity (dark blue) and dissolved oxygen (green) in the seaward (St. LV56-12CTD), on a slope (St. LV56-18CTD) and close to a shelf (St. LV56-24CTD).

The presence of one CSL is the basic indicator of Subarctic water structure in the northern part of the Pacific Ocean and the adjoining seas; and only in the Sea of Okhotsk we observe two cold layers. If the origin of the cold layer, located at depths of 50-100 m, can be attributed to winter convective mixing on the shelf, having a deep layer at depths of 300-400 m has no well-founded hypotheses about its origin. There is an assumption, that this layer is a consequence of slope convection, i.e. there is an immersion of the overcooled shelf waters along a slope to the deeper horizons. Results of our researches in this case do not confirm this hypothesis. We see that the cold intermediate layer on a profile located closer to a shelf (St. LV56-24) has temperature higher, than on St. LV56-18, and it cannot be a source of cold water on a vertical profile of temperature for this station. To carefully study the spread of cold water masses, it is necessary carry out detail polygon investigations on a shelf, and on a seaward part as well.

Possibility to clarify this problem was presented after performance of hydrological section from seaward area to a shelf (Fig. 3.4.1.7). The constructed section on temperature has found out its very low values on a shelf (-1.645°C). This water mass occupies rather small space (of about 30 miles) directly on a shelf. In process of removal from coast there is an increase of temperature up to -0.669°C on water depth of 268 m (St. LV56-34). At the station LV56-33 located in seaward part of a slope, this layer is washed out. In this part of a section isohaline 33.5 is distinctly traced. Rising on the upper horizons, it prevents further advection of cold layers. In Subarctic water structure salinity causes stability of density stratification. Thus, in this section we also do not see the slope convection.

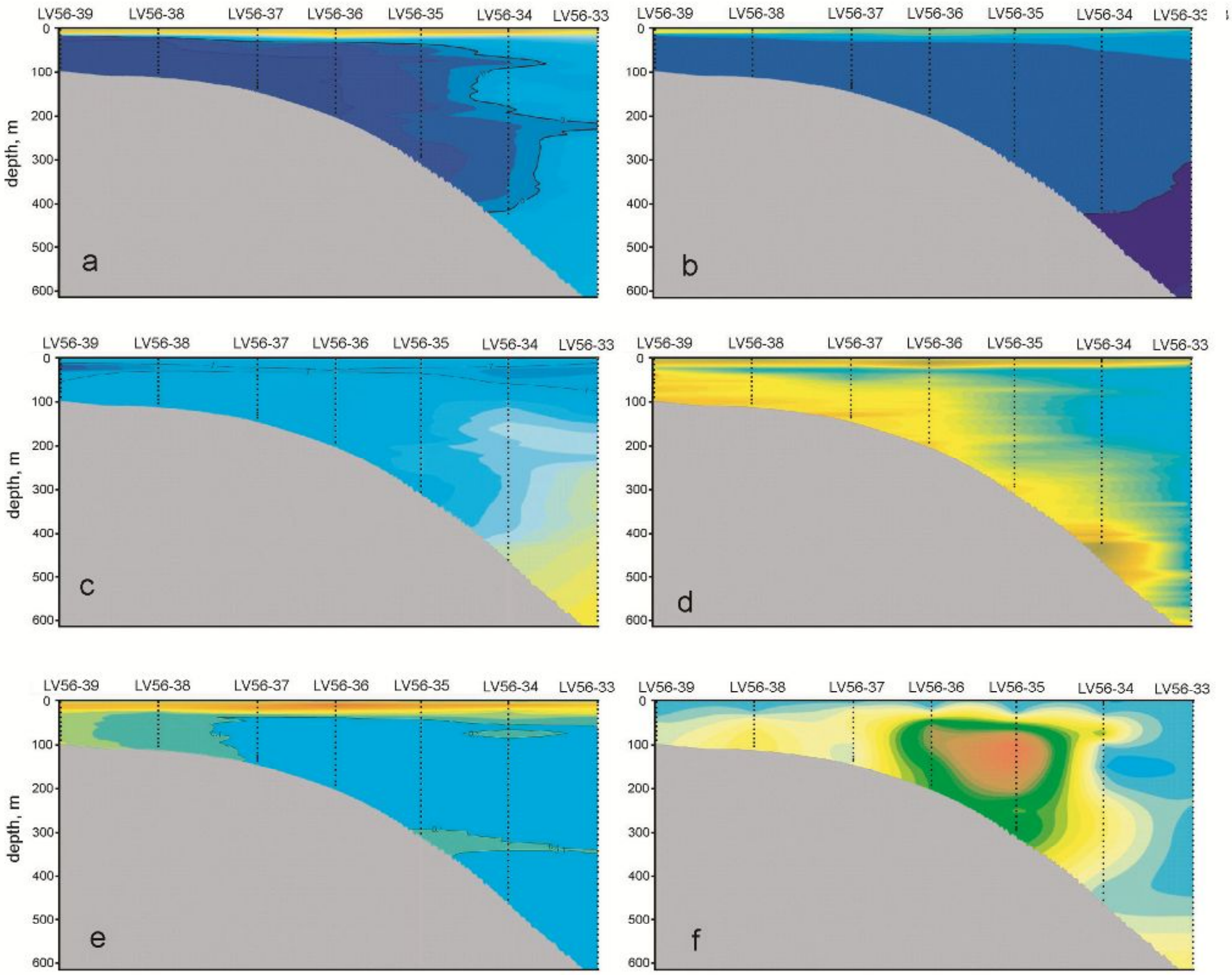



Fig.3.4.1.7. Distribution of temperature (a), salinity (b), dissolved oxygen (c), turbidity (d), fluorescence (e) and methane (f) on the section of seaward area-shelf.

## 3.4.2. Gas Geochemical Investigation

*A. Obzhirov, O. Vereshchagina, E. Korovitskaya*

### Method and devices to measure gas

Gas concentration and volume components of it was measured in column water and sediment. There is analyzing methane, heavy hydrocarbon (C2-C4), O2, N2. Samples of water to measure gas was taken Rosette plastic bottles «Niskin» about 12 horizons from bottom to surface Sea. From Niskin bottle 250 mm water was taken away to measure gas. Samples of sediment collect plastic syringe. Each sample in sediment core picked out every 30-50 cm. To take gas from water and sediment samples was used method Head Space (Fig. 3.4.2.1).

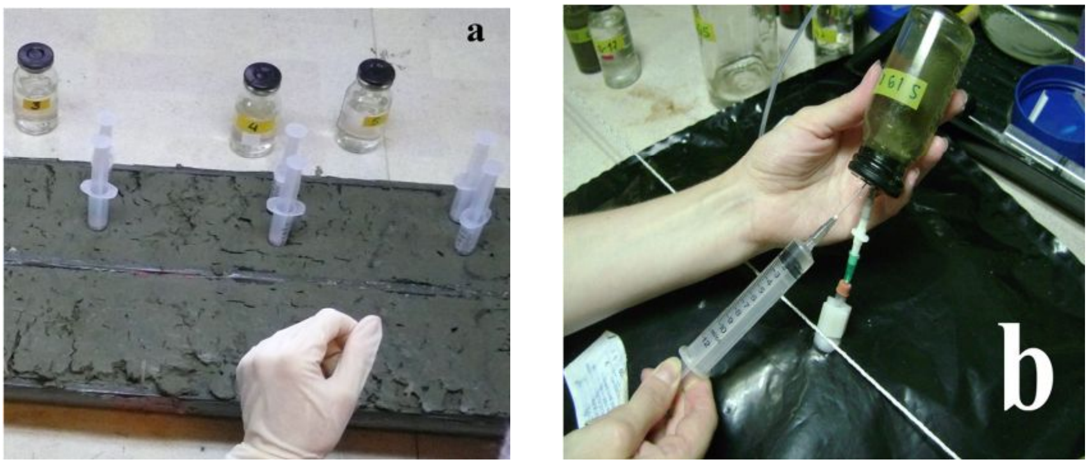



Fig. 3.4.2.1. Procedure to measure gas is using method Head Space. 1-a – choice sample of sediment from core, 1-b – to put helium in salt water with sample of sediment to analyse gas.

Samples of water and sediment shake about 4 hours and after it using syringe take out sample gas. Gas from syringe push to gas chromatograph, in which gas separates in gas component. We use gas chromatograph ‘Kristal-Luks-4000” with flame-ionization detector. Volume of mistake is not more than 10-15 % .

### Result of gas geochemical investigation

Methane and heave hydrocarbon (C2-C4) was measured in 27 CTD stations (Table 3.1.1 and CTD Data from p.121 to p.127) and 21 core stations (Table 3.1.1 and section 3.3.1. Gas Analysis (POI)). In bottom water in area with methane flax methane anomalies were found about 2000-3000 nl/l that more than back ground 100 time. Concentration of heavy hydrocarbon was not more than background. In period investigation in station LV56-2, LV56-4, LV56-6 and LV56-8 was found intermediate layer of water in depth from 50 to 250 m with great anomaly methane (10000 nl/l) and low temperature (-0.5 - -1.5). To check and understand this phenomenon was carried out latitude profile from slop to shelf on stations LV56-33–LV56-39 (Fig. 3.4.2.1). The first data is confirmed. In profile intermediate layer water which contact anomaly methane 10000-11000 nl/l was found. It maybe is going from shelf and intrusion in water mass of slop. Cool water in shelf saturate with methane that is migrating from sediment in area oil-gas deposit and is going to slop. It is important regularity that can help to correct use methane like indicator to prognosis oil-gas deposit, gas hydrate, to examine flux of methane to atmosphere and watch oceanology current.

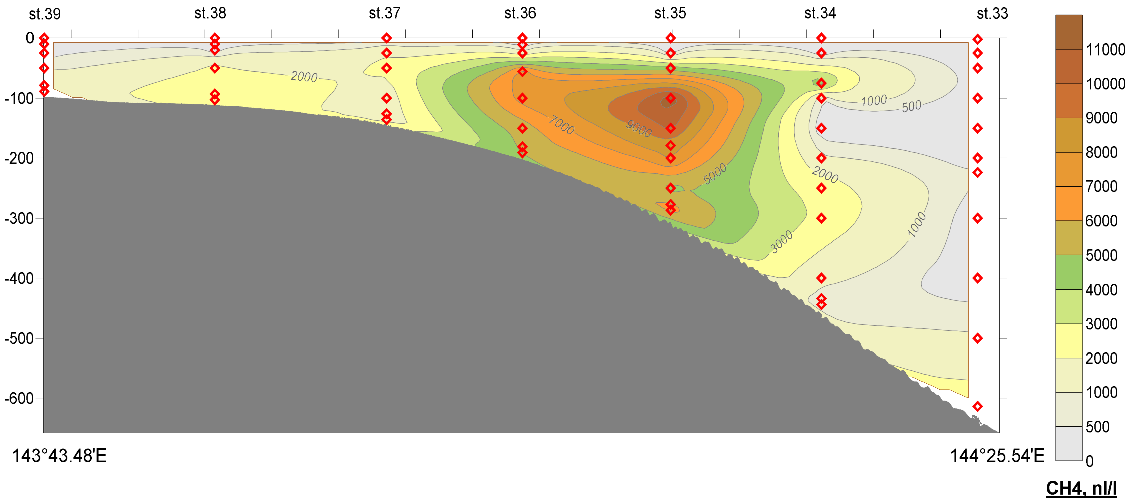



Fig. 3.4.2.2. Gas geochemical profile station LV56-33 – LV56-39 of expedition LV56, OkhotskSea that show intermediate water layer 50-250 m with great methane anomaly (10000-11000 nl/l)

In area investigation of Okhotsk Sea sediment content great anomaly methane concentration. In surface sediment on interval 10 cm methane concentration usually is 1-20 mkM/l. In station LV56-03 where was found gas hydrate it is highest methane concentration – 185 mkM/l. In intervals sediment more deeper methane concentration on increase. It increases very sharply from interval 110 cm. Mostly high methane concentration in this interval is in station LV56-03 (85646 mkM/l) were gas hydrate was found. Other station in this interval change from 100 to 2000 mkM/l). Deeper methane concentration grows and reach 80000-100000 mkM/l on intervals 200-400 cm (Fig. 3.4.2.3). It is great methane anomaly contain in sediment in this area.

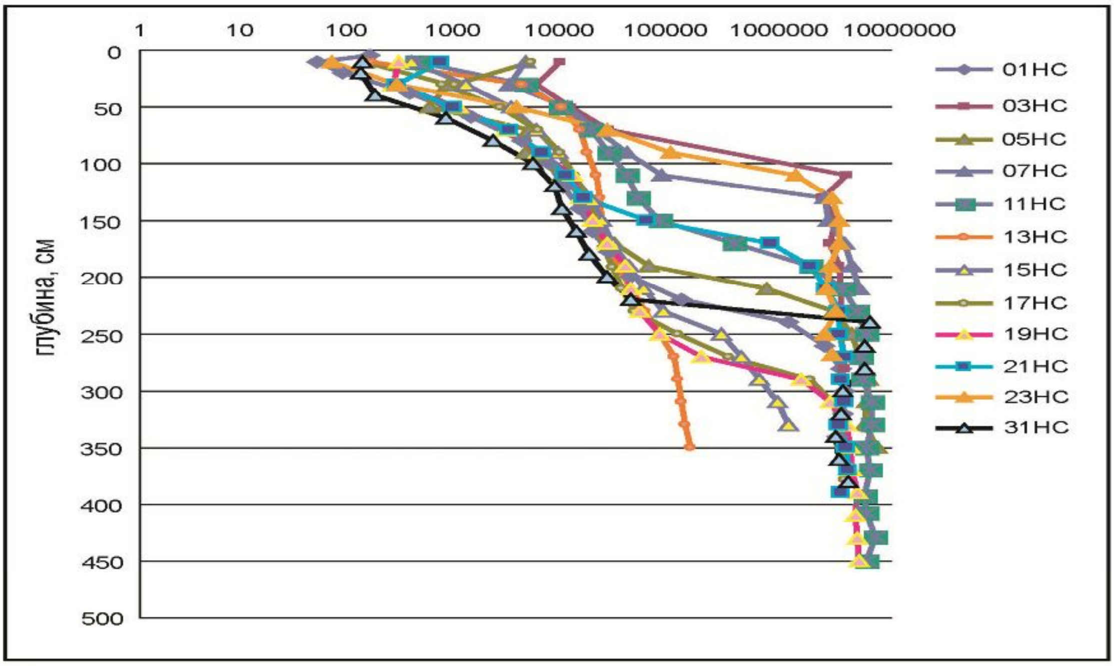
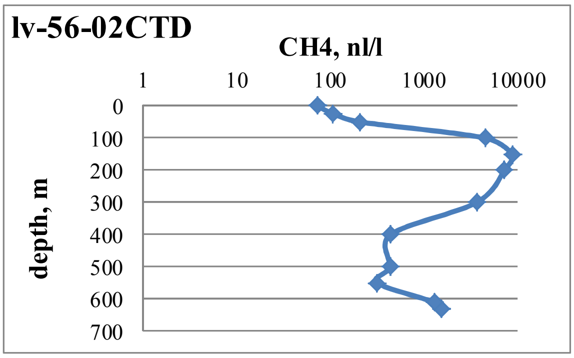



Fig. 3.4.2.3. Methane contain in sediment on stations of expedition LV56, Okhotsk Sea

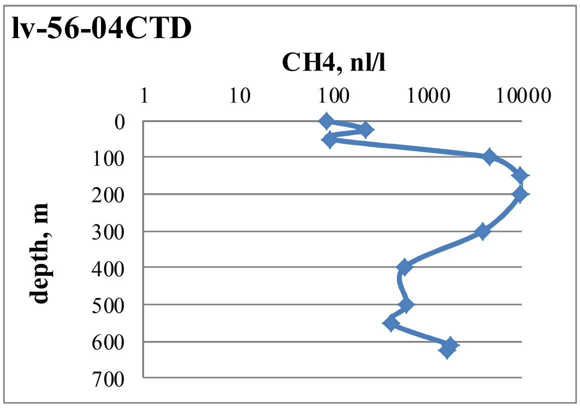
So, in expedition LV56 great methane anomalies was found in the bottom water, intermediate layer water and sediment. It connects mostly with flux of methane that is going from deeper oil-gas bearing layer to surface sediment via zone fault. One part of this methane microbial oxidation that participate to form carbonate concretion in sediment. Microbial methane and other part of thermogenic methane oil-gas deposit form gas hydrate in near surface layer sediment. Some volume methane is going to water and atmosphere.

## CTD Data

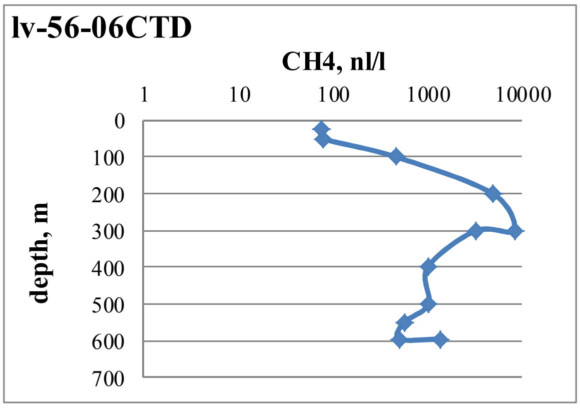
| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-02CTD | 631 | **1560** |
| | 610 | **1306** |
| **Latitude** | 550 | **324** |
| 53°23.170’ | 500 | **438** |
| | 400 | **447** |
| **Longitude** | 300 | **3721** |
| 144°25.849’ | 200 | **7386** |
| | 150 | **8831** |
| | 100 | **4542** |
| | 50 | **209** |
| | 25 | **109** |
| | 0 | **73** |



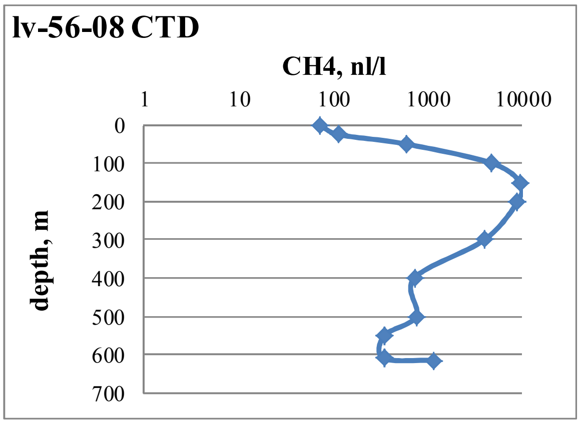

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-04CTD | 625 | **1611** |
| | 610 | **1742** |
| **Latitude** | 550 | **411** |
| 53°23.178’ | 500 | **599** |
| | 400 | **561** |
| **Longitude** | 300 | **3834** |
| 144°25.738’ | 200 | **9614** |
| | 150 | **9401** |
| | 100 | **4583** |
| | 50 | **93** |
| | 25 | **221** |
| | 0 | **86** |



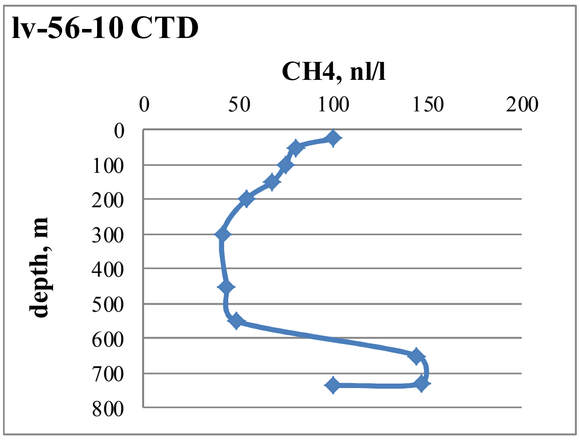

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-06CTD | 595 | **1360** |
| | 595 | **504** |
| **Latitude** | 550 | **561** |
| 53°23.101’ | 500 | **1018** |
| | 400 | **1001** |
| **Longitude** | 300 | **3222** |
| 144°24.692’ | 300 | **8228** |
| | 200 | **4902** |
| | 100 | **468** |
| | 50 | **78** |
| | 25 | **76** |



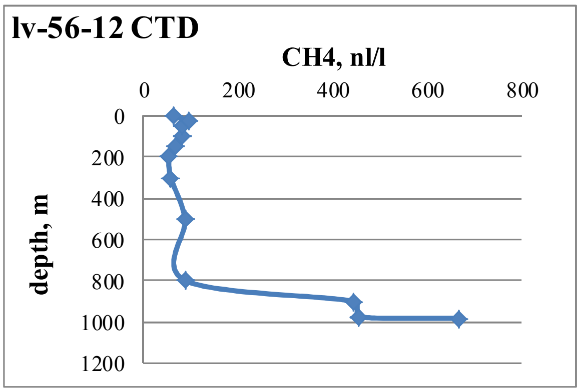
| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-08CTD | 615 | **1161** |
| | 610 | **342** |
| **Latitude** | 550 | **346** |
| 53°22.204’ | 500 | **755** |
| | 400 | **720** |
| **Longitude** | 300 | **3973** |
| 144°25.468’ | 200 | **8882** |
| | 150 | **9472** |
| | 100 | **4775** |
| | 50 | **594** |
| | 25 | **112** |
| | 0 | **72** |



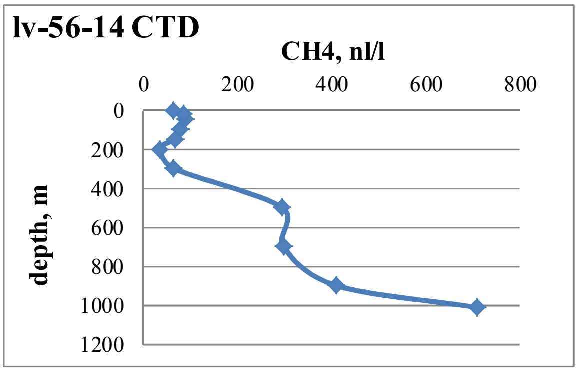

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-10CTD | 736 | **100** |
| | 730 | **147** |
| **Latitude** | 650 | **144** |
| 54°43.411’ | 550 | **49** |
| | 450 | **44** |
| **Longitude** | 300 | **42** |
| 144°09.970’ | 200 | **54** |
| | 150 | **68** |
| | 100 | **75** |
| | 50 | **81** |
| | 25 | **100** |



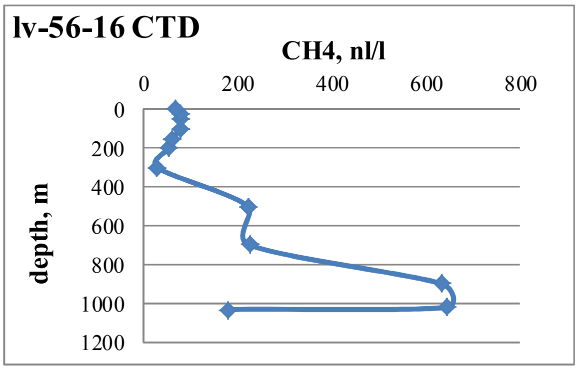

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-12CTD | 983 | **667** |
| | 975 | **455** |
| **Latitude** | 900 | **443** |
| 54°13.058’ | 800 | **89** |
| | 500 | **87** |
| **Longitude** | 300 | **57** |
| 144°19.304’ | 200 | **54** |
| | 150 | **65** |
| | 100 | **82** |
| | 50 | **82** |
| | 25 | **94** |
| | 0 | **64** |



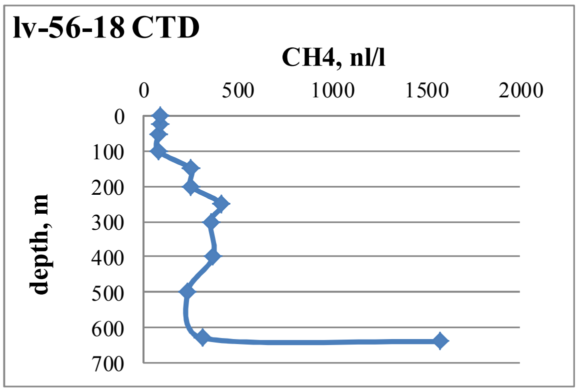
| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-14CTD | 1012 | **707** |
| | 900 | **410** |
| **Latitude** | 700 | **298** |
| 54°13.084’ | 500 | **295** |
| | 300 | **65** |
| **Longitude** | 200 | **35** |
| 144°21.127’ | 150 | **66** |
| | 100 | **77** |
| | 50 | **88** |
| | 25 | **85** |
| | 0 | **66** |



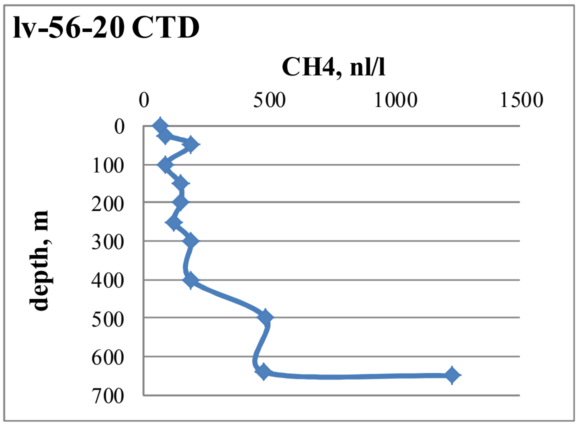

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-16CTD | 1032 | **178** |
| | 1020 | **644** |
| **Latitude** | 900 | **634** |
| 54°09.488’ | 700 | **225** |
| | 500 | **221** |
| **Longitude** | 300 | **29** |
| 144°21.040’ | 200 | **55** |
| | 150 | **61** |
| | 100 | **78** |
| | 50 | **80** |
| | 20 | **77** |
| | 0 | **69** |



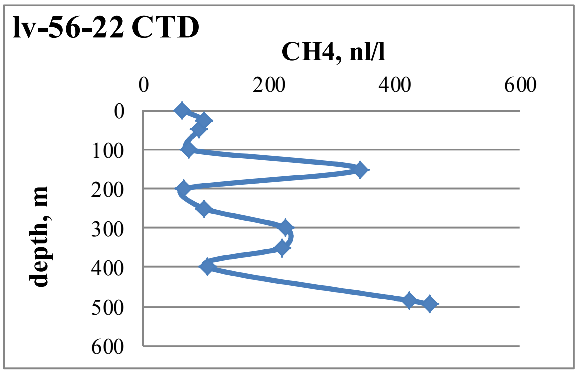

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-18CTD | 640 | **1571** |
| | 630 | **314** |
| **Latitude** | 500 | **234** |
| 54°10.265’ | 400 | **370** |
| | 300 | **355** |
| **Longitude** | 250 | **411** |
| 144°02.801’ | 200 | **254** |
| | 150 | **248** |
| | 100 | **79** |
| | 50 | **80** |
| | 25 | **88** |
| | 0 | **90** |



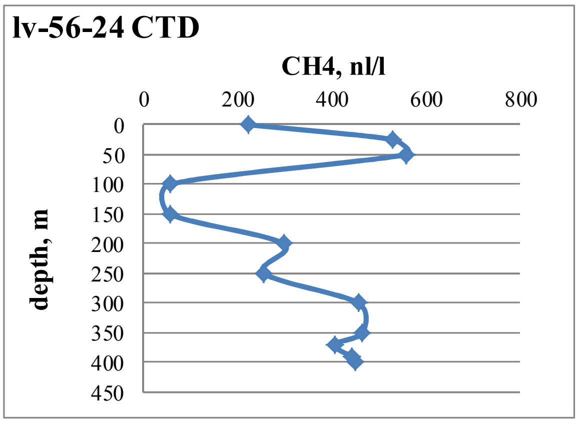
| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-20CTD | 650 | **1225** |
| | 640 | **479** |
| **Latitude** | 500 | **488** |
| 53°46.428’ | 400 | **186** |
| | 300 | **187** |
| **Longitude** | 250 | **121** |
| 144°12.407’ | 200 | **149** |
| | 150 | **146** |
| | 100 | **88** |
| | 50 | **190** |
| | 25 | **89** |
| | 0 | **64** |



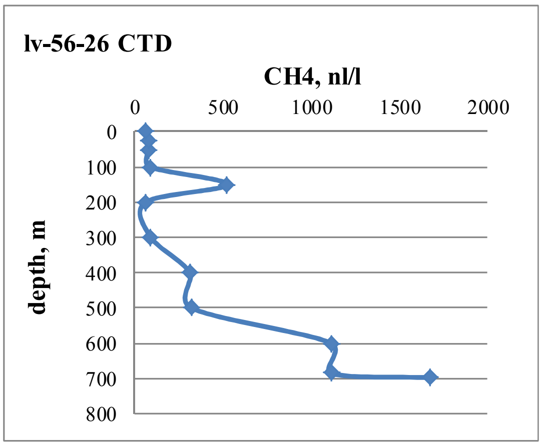

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-22CTD | 495 | **457** |
| | 485 | **424** |
| **Latitude** | 400 | **102** |
| 53°41.875’ | 350 | **222** |
| | 300 | **227** |
| **Longitude** | 250 | **96** |
| 144°11.901’ | 200 | **65** |
| | 150 | **345** |
| | 100 | **72** |
| | 50 | **88** |
| | 25 | **96** |
| | 0 | **62** |



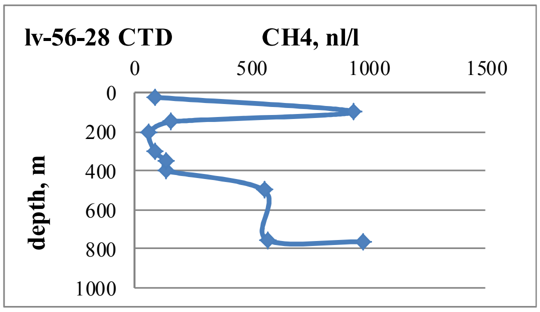

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-24CTD | 400 | **449** |
| | 390 | **441** |
| **Latitude** | 370 | **405** |
| 53°34.150’ | 350 | **465** |
| | 300 | **455** |
| **Longitude** | 250 | **256** |
| 144°12.628’ | 200 | **297** |
| | 150 | **55** |
| | 100 | **57** |
| | 50 | **557** |
| | 25 | **530** |
| | 0 | **224** |



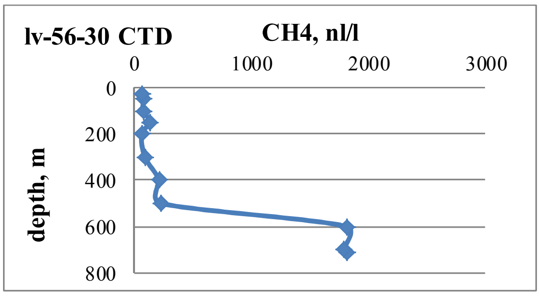
| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-26CTD | 698 | **1673** |
| | 685 | **1111** |
| Latitude | 600 | **1113** |
| 53°21.614’ | 500 | **321** |
| | 400 | **313** |
| Longitude | 300 | **93** |
| 144°29.534’ | 200 | **63** |
| | 150 | **523** |
| | 100 | **86** |
| | 50 | **81** |
| | 25 | **82** |
| | 0 | **64** |



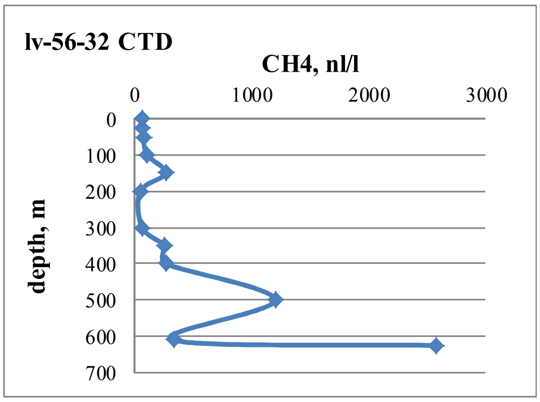

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-28CTD | 764 | **977** |
| | 754 | **567** |
| Latitude | 500 | **553** |
| 53°22.025’ | 400 | **135** |
| | 350 | **133** |
| Longitude | 300 | **86** |
| 144°31.975’ | 200 | **65** |
| | 150 | **158** |
| | 100 | **934** |
| | 25 | **91** |



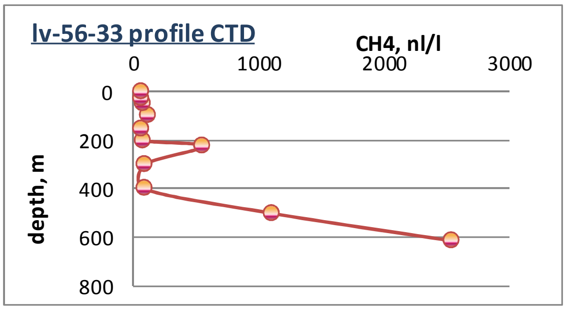

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-30CTD | 710 | **1815** |
| | 700 | **1785** |
| Latitude | 600 | **1811** |
| 53°21.591’ | 500 | **225** |
| | 400 | **212** |
| Longitude | 300 | **93** |
| 144°30.257’ | 200 | **65** |
| | 150 | **138** |
| | 100 | **78** |
| | 50 | **80** |
| | 25 | **65** |



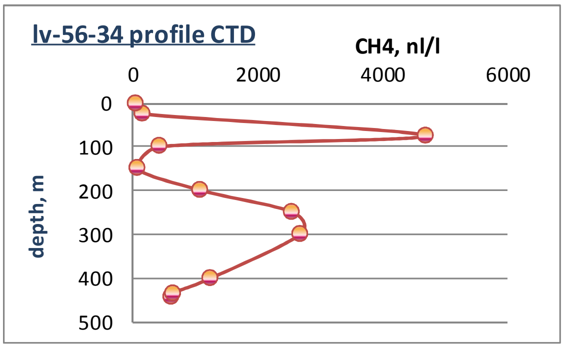

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-32CTD | 626 | **2569** |
| | 611 | **333** |
| Latitude | 500 | **1201** |
| 53°22.486’ | 400 | **271** |
| | 350 | **255** |
| Longitude | 300 | **65** |
| 144°26.552’ | 200 | **51** |
| | 150 | **269** |
| | 100 | **110** |
| | 50 | **78** |
| | 25 | **74** |
| | 0 | **62** |



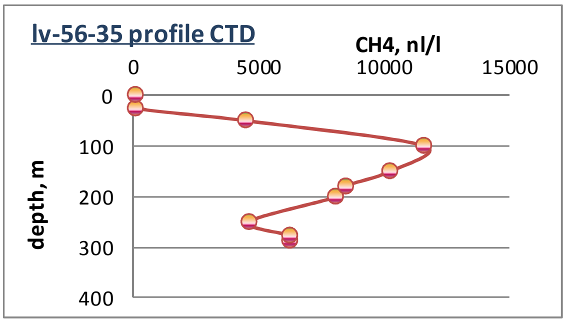
| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-33CTD | 614 | **2544** |
| | 500 | **1100** |
| Latitude | 400 | **89** |
| 53°22.885’ | 300 | **89** |
| | 224 | **557** |
| Longitude | 200 | **74** |
| 144°25.666’ | 150 | **61** |
| | 100 | **116** |
| | 50 | **84** |
| | 25 | **64** |
| | 0 | **70** |



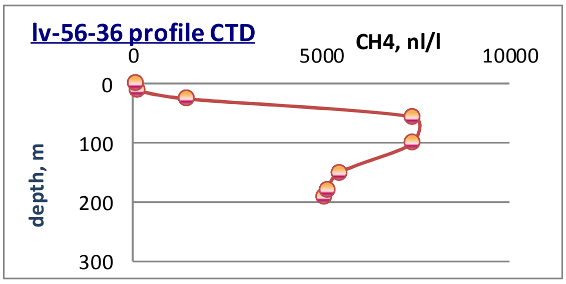

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-34CTD | 444 | **635** |
| | 434 | **651** |
| Latitude | 400 | **1261** |
| 53°22.918’ | 300 | **2684** |
| | 250 | **2564** |
| Longitude | 200 | **1097** |
| 144°18.659’ | 150 | **74** |
| | 100 | **441** |
| | 75 | **4684** |
| | 25 | **150** |
| | 0 | **66** |



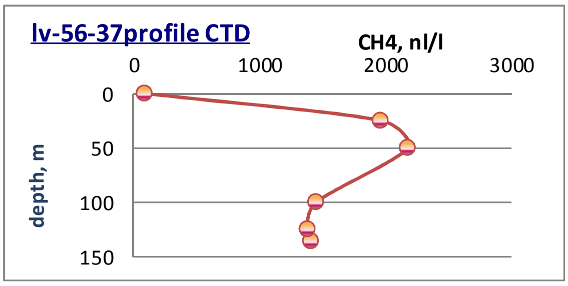

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-35CTD | 287 | **6257** |
| | 277 | **6265** |
| Latitude | 250 | **4624** |
| 53°23.097’ | 200 | **8119** |
| | 179 | **8476** |
| Longitude | 150 | **10250** |
| 144°11.894’ | 100 | **11623** |
| | 50 | **4511** |
| | 25 | **135** |
| | 0 | **107** |



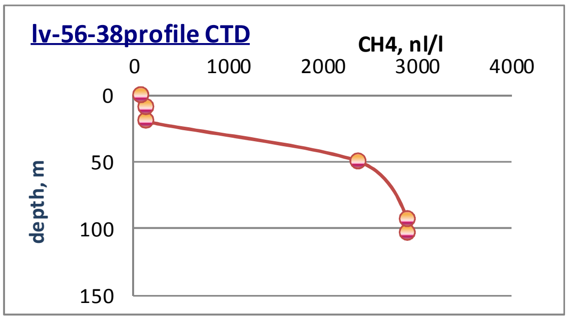

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-36CTD | 191 | **5084** |
| | 181 | **5156** |
| Latitude | 150 | **5470** |
| 53°23.112’ | 100 | **7429** |
| | 56 | **7443** |
| Longitude | 25 | **1410** |
| 144°05.251’ | 11 | **124** |
| | 0 | **94** |



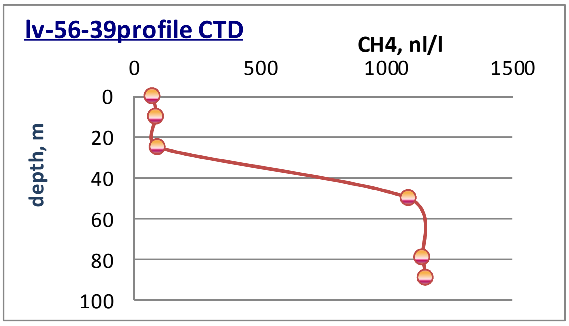
| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-37CTD | 136 | **1408** |
| | 126 | **1378** |
| **Latitude** | 100 | **1452** |
| 53°23.081’ | 50 | **2179** |
| | 25 | **1959** |
| **Longitude** | 0 | **88** |
| 143°59.147’ | | |



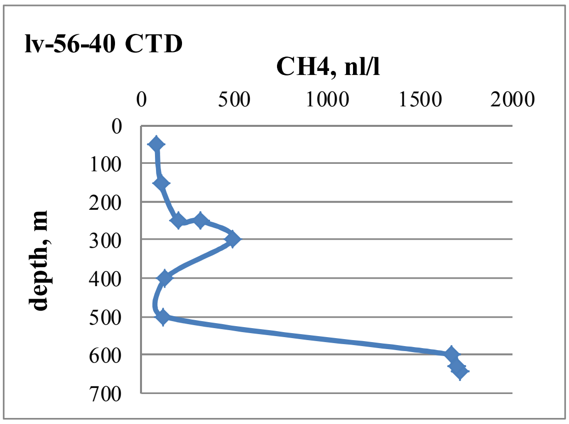

| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-38CTD | 103 | **2903** |
| | 93 | **2906** |
| **Latitude** | 50 | **2384** |
| 53°23.056’ | 20 | **141** |
| | 10 | **139** |
| **Longitude** | 0 | **75** |
| 143°51.449’ | | |




| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-39CTD | 89 | **1160** |
| | 79 | **1144** |
| **Latitude** | 50 | **1091** |
| 53°23.119’ | 25 | **96** |
| **Longitude** | 10 | **90** |
| 143°43.798’ | 0 | **77** |




| Station | Depth, m | CH4, nl/l |
|---|---|---|
| lv-56-40CTD | 643 | **1714** |
| | 629 | **1700** |
| **Latitude** | 600 | **1672** |
| 53°30.916’ | 500 | **122** |
| | 400 | **133** |
| **Longitude** | 300 | **493** |
| 144°23.273’ | 250 | **317** |
| | 250 | **201** |
| | 150 | **107** |
| | 50 | **85** |



## Underway Data

| No. | lat | | long | | CH4 nl/l | No. | lat | | long | | CH4 nl/l |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 45° | 59,56 | 143° | 23,587 | 261 | 31 | 47° | 52,163 | 146° | 8,417 | 212 |
| 2 | 46° | 4,073 | 143° | 29,488 | 300 | 32 | 47° | 58,698 | 146° | 8,408 | 65 |
| 3 | 46° | 11,123 | 143° | 33,936 | 350 | 33 | 47° | 58,698 | 146° | 8,408 | 193 |
| 4 | 46° | 16,015 | 143° | 37,042 | 404 | 34 | 48° | 4,686 | 146° | 8,396 | 60 |
| 5 | 46° | 21,658 | 143° | 40,676 | 419 | 35 | 48° | 4,686 | 146° | 8,396 | 218 |
| 6 | 46° | 27,53 | 143° | 41,088 | 251 | 36 | 48° | 9,791 | 146° | 8,41 | 168 |
| 7 | 46° | 36,858 | 143° | 40,264 | 257 | 37 | 48° | 9,791 | 146° | 8,41 | 60 |
| 8 | 46° | 48,96 | 143° | 39,143 | 232 | 38 | 48° | 15,134 | 146° | 8,4 | 175 |
| 9 | 46° | 59,806 | 143° | 38,153 | 214 | 39 | 48° | 20,134 | 146° | 8,412 | 158 |
| 10 | 47° | 10,79 | 143° | 37,156 | 191 | 40 | 48° | 20,134 | 146° | 8,412 | 61 |
| 11 | 47° | 24,06 | 143° | 36,272 | 246 | 41 | 48° | 31,978 | 146° | 5,521 | 177 |
| 12 | 47° | 24,06 | 143° | 36,272 | 128 | 42 | 48° | 42,8 | 146° | 2,924 | 167 |
| 13 | 47° | 24,06 | 143° | 36,272 | 124 | 43 | 48° | 54,078 | 146° | 0,217 | 179 |
| 14 | 47° | 23,989 | 143° | 43,67 | 119 | 44 | 49° | 1,464 | 145° | 58,442 | 158 |
| 15 | 47° | 23,989 | 143° | 43,67 | 213 | 45 | 49° | 11,126 | 145° | 56,112 | 166 |
| 16 | 47° | 23,996 | 143° | 51,052 | 187 | 46 | 49° | 22,067 | 145° | 53,455 | 159 |
| 17 | 47° | 23,999 | 143° | 58,754 | 86 | 47 | 49° | 31,22 | 145° | 51,229 | 156 |
| 18 | 47° | 23,999 | 143° | 58,754 | 177 | 48 | 49° | 42,474 | 145° | 48,431 | 170 |
| 19 | 47° | 24,002 | 144° | 7,462 | 92 | 49 | 49° | 52,95 | 145° | 45,874 | 167 |
| 20 | 47° | 24,002 | 144° | 7,462 | 173 | 50 | 50° | 6,602 | 145° | 42,533 | 171 |
| 21 | 47° | 23,995 | 144° | 16,456 | 97 | 51 | 50° | 15,6 | 145° | 40,282 | 173 |
| 22 | 47° | 23,995 | 144° | 16,456 | 190 | 52 | 50° | 26,749 | 145° | 37,499 | 154 |
| 23 | 47° | 23,993 | 144° | 23,168 | 179 | 53 | 50° | 38,106 | 145° | 34,716 | 168 |
| 24 | 47° | 25,542 | 144° | 32,816 | 177 | 54 | 50° | 49,685 | 145° | 31,799 | 188 |
| 25 | 47° | 28,14 | 144° | 47,962 | 180 | 55 | 51° | 2,31 | 145° | 28,576 | 164 |
| 26 | 47° | 30,672 | 145° | 2,892 | 210 | 56 | 51° | 11,224 | 145° | 26,398 | 163 |
| 27 | 47° | 33,166 | 145° | 17,375 | 233 | 57 | 51° | 20,744 | 145° | 24,664 | 173 |
| 28 | 47° | 35,9 | 145° | 30,743 | 281 | 58 | 51° | 20,744 | 145° | 24,664 | 98 |
| 29 | 47° | 40,98 | 145° | 44,665 | 168 | 59 | 51° | 28,734 | 145° | 24,671 | 146 |
| 30 | 47° | 47,953 | 146° | 3,518 | 146 | 60 | 51° | 28,734 | 145° | 24,671 | 79 |

| No. | lat | | long | | CH4 nl/l | No. | lat | | long | | CH4 nl/l |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 51° | 33,778 | 145° | 24,671 | **149** | 91 | 53° | 22,2 | 144° | 27,665 | **139** |
| 62 | 51° | 33,778 | 145° | 24,671 | **87** | 92 | 53° | 22,704 | 144° | 27,6 | **163** |
| 63 | 51° | 39,266 | 145° | 24,65 | **155** | 93 | 53° | 22,612 | 144° | 26,263 | **159** |
| 64 | 51° | 39,266 | 145° | 24,65 | **92** | 94 | 53° | 22,681 | 144° | 25,477 | **148** |
| 65 | 51° | 44,55 | 145° | 24,689 | **157** | 95 | 53° | 22,675 | 144° | 24,746 | **146** |
| 66 | 51° | 44,55 | 145° | 24,689 | **91** | 96 | 53° | 22,668 | 144° | 24,019 | **147** |
| 67 | 51° | 50,376 | 145° | 24,67 | **174** | 97 | 53° | 22,686 | 144° | 22,777 | **144** |
| 68 | 51° | 50,376 | 145° | 24,67 | **83** | 98 | 53° | 23,134 | 144° | 22,872 | **126** |
| 69 | 51° | 57,157 | 145° | 24,649 | **147** | 99 | 53° | 23,148 | 144° | 24,144 | **123** |
| 70 | 51° | 57,157 | 145° | 24,649 | **68** | 100 | 53° | 23,164 | 144° | 24,93 | **131** |
| 71 | 52° | 2,189 | 145° | 23,153 | **144** | 101 | 53° | 23,159 | 144° | 25,614 | **126** |
| 72 | 52° | 11,26 | 145° | 16,76 | **167** | 102 | 53° | 23,160 | 144° | 26,405 | **143** |
| 73 | 52° | 32,22 | 145° | 9,201 | **134** | 103 | 53° | 23,152 | 144° | 27,724 | **134** |
| 74 | 52° | 34,394 | 145° | 0,827 | **143** | 104 | 53° | 23,632 | 144° | 27,628 | **139** |
| 75 | 52° | 39,403 | 144° | 57,332 | **147** | 105 | 53° | 23,640 | 144° | 26,293 | **146** |
| 76 | 52° | 50,681 | 144° | 49,453 | **136** | 106 | 53° | 23,640 | 144° | 25,475 | **136** |
| 77 | 53° | 0,39 | 144° | 42,856 | **135** | 107 | 53° | 23,646 | 144° | 24,731 | **136** |
| 78 | 53° | 8,023 | 144° | 37,235 | **132** | 108 | 53° | 23,645 | 144° | 24,020 | **138** |
| 79 | 53° | 18,574 | 144° | 29,85 | **130** | 109 | 53° | 23,640 | 144° | 22,717 | **134** |
| 80 | 53° | 21,697 | 144° | 27,558 | **136** | | | | | | |
| 81 | 53° | 21,722 | 144° | 26,178 | **132** | | | | | | |
| 82 | 53° | 21,727 | 144° | 25,145 | **134** | | | | | | |
| 83 | 53° | 21,719 | 144° | 24,636 | **128** | | | | | | |
| 84 | 53° | 21,725 | 144° | 24,008 | **129** | | | | | | |
| 85 | 53° | 21,714 | 144° | 22,67 | **130** | | | | | | |
| 86 | 53° | 22,19 | 144° | 23,046 | **122** | | | | | | |
| 87 | 53° | 22,196 | 144° | 24,128 | **129** | | | | | | |
| 88 | 53° | 22,188 | 144° | 24,907 | **141** | | | | | | |
| 89 | 53° | 22,189 | 144° | 25,699 | **136** | | | | | | |
| 90 | 53° | 22,194 | 144° | 26,32 | **139** | | | | | | |

# 4. APPENDIX

## 4.1. Daily Situation Report

| | | |
|---|---|---|
| Aug 08 Mon | | Laventyev could not leave Port Vladivostok due to Typhoon. |
| Aug 09 Tue | | Lavrentyev left Vladivostok. |
| Aug 12 Fri | 04:00 | Lavrentyev arrived at Korsakov. |
| | 10:00 | KOPRI (Jin, Hong) and KIT (Shoji, Minami, Hachikubo, Soramoto, Dewa) members got on board. Clear sky but windy. Customs clearance prepared. |
| | 18:00 | Customs clearance completed, but too windy. |
| | 20:00 | Weather improved a lot. Operation Meeting (Captain, AO, HS, BB and NN) on weather. Low pressure system stays at midway between Korsakov and Study Area No.1, and moves toward north very slowly. Captain wants to stay at Korsakov overnight and leave early morning tomorrow. |
| Aug 13 Sat | 06:00 | Cloudy but calm. |
| | 08:00 | Lavrentyev left Korsakov. Hydro-acoustic survey (using 1470 m/s sound velocity to calculate water depth) started. |
| | 09:00 | Operation Meeting (AO, HS, YJ, JH, BB, AK, AS, NN, AD and VP) for schedule of SSGH-11 operations. |
| | 12:00 | Lavrentyev sails at 46º5.841'N, 143º13.311'E by 10.8 kts. |
| | 14:00 | Plenary Meeting for introducing members and schedule plan. |
| | 21:14 | Arrived at Study Area No.3 for Sparker Survey (first WE line with 6 kts). |
| | 22:35 | Flare No.2 observed with gas chimney at 740 mWD. |
| Aug 14 Sun | 06:30 | Cloudy but calm. Slightly Pitching/Rolling. |
| | 08:02 | Lavrentyev sailed at 47º34.816'N, 145º26.869'E between two Sparker survey lines by 10.7 kts. No flare observed after Flare No.2. |
| | 09:00 | Operation Meeting (AO, HS, YJ, JH, BB, AD, AS and NN). Weather seems OK. |
| | 11:30 | Sparker survey (SN line, second line) started. |
| | 16:00 | Rain. |
| | 17:00 | A time-table plan of SSGH-11 operation was distributed. No Rain but Foggy. |
| | 17:10 | Sparker survey completed in Study Area No.3. Lavrentyev left for Study Area No.2. |
| | 19:52 | Lavrentyev sailed at 48º50.320'N, 146º1.083'E by 10.6 kts. |
| Aug 15 Mon | 06:00 | Clear and calm. Slightly Pitching/Rolling. Flare No.3 (50º8.969'N, 145º41.959'E) was observed at a bottom of a pockmark (600 m wide and 20 m deep at 587 mWD) during the transit last night. This might be a southern limit |

of NE Sakhalin seep area.

09:00 Cloudy but calm. Slightly Pitching/Rolling. Operation Meeting (AO, HS, YJ, JH, BB, AD, AS and NN). Weather seems OK.

10:00 Sparker survey (SN line) started at Study Area No.2.

17:50 Sparker survey completed. No flare observed during the survey. Lavrentyev left Study Area No.2 for Study Area No.1

Aug 16 Tue 02:19 Lavrentyev arrived at Study Area No.1 (region No.5). Hydro-acoustic survey (nine 3-to-5 nm lines with 6 kts) and BS (Bathymetric Survey using 1500 m/s sound velocity to calculate water depth) started.

06:00 Cloudy but calm. Two flares were observed during HA survey by this time.

08:20 HA and BS survey completed at Region No.5. Four flares were observed during the survey.

08:30 Core site candidates were selected by OM (AO, HS, YJ and BB).

A new winch was installed last June (Wire Diameter; 18 mm, Wire Length; 7 km). A Hydro-corer was used for coring during this cruising (Length; 6 m, Inner Diameter; 125 mm, Outer Diameter; 138 mm, Weight; 300 kg).

09:41 The corer was put down to a height of 65 m from sea bottom and released to free fall.

09:52 LV56-01HC core was retrieved from top of a spur on a crest line of sedimentary wave feature (53º23.106'N, 144º25.495'E, 624 mWD). The core length was 360 cm including 12 cm of core catcher part. No GH observed. A worm at the top. Holocene layer was 15 cm from the top. Glendonite was observed at a core depth of 250 cm.

10:05 CTD survey was conducted (LV56-02CTD).

11:40 LV56-03HC core was retrieved from a flare position within 200 m from LV56-01HC coring site (53º23.127'N, 144º25.593'E, 623 mWD). The core length was 335 cm including 15 cm of core catcher part. GH layers were observed at core depths of 250 and 270 cm, and in the core catcher. Holocene layer was 1 cm thick at the top.

11:50 CTD survey was conducted (LV56-04CTD).

14:05 LV56-05HC core was retrieved from top of a spur (53º22.865'N, 144º24.957'E, 613 mWD). The core length was 376 cm including 14 cm of core catcher part. No GH observed. Holocene/Pleistocene boundary was not visible. Carbonate accretion at core depths of 260 and 270 cm. Cracking nose at the core bottom.

14:15 CTD survey was conducted (LV56-06CTD).

16:23 LV56-07HC core was retrieved from top of a spur (53º21.860'N, 144º26.050'E, 632 mWD). The core length was 227 cm including 2 cm of core catcher part. No GH observed. Holocene layer was 10 cm from the top. Shell fragments at core depths of 40 and 70 cm. Carbonate accretion at a core depth of 200 cm. Gas swelling features observed below a core depth of 140 cm.

16:35 CTD survey was conducted (LV56-08CTD).

17:30 Lavrentyev left Region No.5 for northern area of Channel. Cloudy and occasional sun shine. Sea surface was calm.

Aug 17 Wed 02:00 Lavrentyev arrived at Northwestern edge of Study Area No.1, and Sparker Survey (WE line) started.

06:00 Cloudy and foggy, but calm.

07:30 Sparker Survey shifted to the second line (EW line with an interval of about 5 nm to the WE line). One gas chimney was observed, but no other features including flare, packmark and fault were observed during the WE line survey.

09:00 Operation Meeting (AO, HS, YJ, JH, BB, AS, AD and NN). Weather seems OK. One core should be retrieved at a water depth of 600 m along the EW line for KOPRI oceanology and KIT reference purposes after Sparker Survey.

11:30 Lavrentyev sailed at 54º45.007'N, 144º15.096'E by 5.2 kts. Estimated time of completion of Sparker EW line survey was 14:00. Cloudy and Foggy. Slightly pitching and rolling.

14:10 Sparker Survey completed. Lavrentyev returned to a coring site of 600 mWD along Sparker EW line.

15:00 Coring site was changed to a site of 700 mWD around 54º44.925'N, 144º9.799'E for a softer sea bottom. Hydro-core was extended by connecting 4 m long tube (total length of corer; 10 m).

15:57 Corer was put into water and lowered by a speed of 1.8 m/s.

16:21 LV56-09HC core was retrieved from a site on a Sparker survey line (EW line) at a water depth of around 700 m (54º44.935'N, 144º09.698'E, 740 mWD). The core length was 5 cm containing only a stone (3 cm) and several pebbles (5 mm). Oceanographic and Reference core was decided to be taken from another place (West of "North of LFZ").

17:05 CTD survey was conducted after fixing the apparatus (LV56-10-1CTD).

17:48 Lavrentyev left North of Channel area for North of LFZ area.

18:45 Lavrentyev passed Channel (140 m deep). A faint image of flare was observed at the Channel, possibly VNIIOkeangeologia Flare.

21:15 Lavrentyev arrived at North of LFZ.

21:35 Sparker, HA and BS surveys were started.

| | | |
|---|---|---|
| Aug 18 Thu | 06:00 | Clear and calm. |
| | 06:42 | Lavrentyev sailed at 54º9.002'N, 144º16.864'E by 5.3 kts. Seven new flares were observed during the survey. |
| | 07:16 | Lavrentyev passed linear seepage at the second time, but no Gas Chimney/Flare was observed. |
| | 08:15 | The survey finished and OM (AO, HS, YJ and BB) selected the first coring site at the North of LFZ area. |
| | 09:54 | LV56-11HC core was retrieved from a site of Seepage Structure with Flare (54º12.914'N, 144º19.456'E, 1000 mWD). The core length was 485 cm including 10 cm of core catcher part. No GH observed. All Holocene layers from top to the bottom. Cracks due to gas swelling observed below a core depth of 280 cm. |
| | 10:00 | CTD survey was conducted (LV56-12CTD). |
| | 10:44 | CTD survey completed. |
| | 12:37 | LV56-13HC core was retrieved from a site of Seepage Structure with Flare (54º12.517'N, 144º20.632'E, 1015 mWD). The core length was 379 cm including 15 cm of core catcher part. No GH observed. All Holocene layers from top to the bottom. Shell fragments were contained in a core catcher. |
| | 12:44 | CTD survey was conducted (LV56-14CTD). |
| | 13:28 | CTD survey completed. |
| | 13:37 | Lavrentyev moved to a southern site in the North of LFZ area. |
| | 15:33 | LV56-15HC core was retrieved from a site of Seepage Structure with Flare and Gas Chimney (54º9.145'N, 144º20.468'E, 1045 mWD). The core length was 363 cm including 10 cm of core catcher part. No GH observed. All Holocene layers from top to the bottom. |
| | 15:37 | CTD survey was conducted (LV56-16CTD). |
| | 16:24 | CTD survey completed. |
| | 16:35 | Lavrentyev left North of LFZ area to the West for a shallower depth site for Oceanographic core (KOPRI). Clear and calm. |
| | 17:48 | Lavrentyev arrived at a coring site. |
| | 18:12 | LV56-17HC core was retrieved (54º9.80'N, 144º2.050'E, 640 mWD). The core length was 400 cm including 12 cm of core catcher part. No GH observed. Almost all Holocene layers from top to the bottom. $H_2S$ odor near the bottom of the core. Disturbances of layers by worms were observed at the upper part of the core. KOPRI decided not to take this core for Oceanological analyses. |

| | | |
|---|---|---|
| | 18:14 | CTD survey was conducted (LV56-18CTD). |
| | 18:49 | CTD survey completed. |
| | 19:05 | Lavrentyev left the site for Junction of LFZ. |
| | 21:30 | Lavrentyev arrived at Junction of LFZ, and Sparker, HA and BS surveys started. |
| Aug 19 Fri | 06:00 | Cloudy but calm. Survey continued. |
| | 07:50 | OM (AO, HS, YJ, JH, BB, AS, AD and NN). Weather seems OK. Geophysical survey needed three to four hours to be completed. Three flares were observed during the survey, including one at water depth of 350 m. Coring time should be postponed accordingly. Oceanological core (KOPRI, one half core) could be taken when an appropriate core was retrieved. |
| | 11:50 | Geophysical survey was completed at Junction of LFZ area. |
| | 14:55 | LV56-19HC core was retrieved at a flare No.56 (53º46.439'N, 144º12.211'E, 665 mWD). The core length was 480 cm including 11 cm of core catcher part. No GH observed. All Holocene layers from top to the bottom. Disturbances of layers by worms were observed at the upper part of the core. Carbonate concretion was observed at a core depth of 310 cm. |
| | 15:08 | CTD survey was conducted (LV56-20CTD). |
| | 15:40 | CTD survey completed. Lavrentyev moved to a site of flare No.57. |
| | 17:01 | LV56-21HC core was retrieved at a flare No.57 (53º42.230'N, 144º12.176'E, 506 mWD). The core length was 436 cm including 16 cm of core catcher part. No GH observed. Top 15 or 20 cm is Holocene layers and the deeper part is Pleistocene layers. Glendonite at 140 cm depth. Gas cracks below 300 cm depth. Hydrotroilite layer below 310 cm depth. |
| | 17:05 | CTD survey was conducted (LV56-22CTD). |
| | 15:31 | CTD survey completed. |
| | 17:45 | Lavrentyev moved to a site of flare No.59. |
| | 19:32 | LV56-23HC core was retrieved at a flare No.59 (53º34.154'N, 144º13.018'E, 430 mWD). The core length was 284 cm including 10 cm of core catcher part. No GH observed. Top 15 cm is Holocene layers and the deeper part is Pleistocene layers. Carbonate accretion at 70 and 110 cm depths. Gas cracks below 160 cm depth. |
| | 19:37 | CTD survey was conducted (LV56-23CTD). |
| | 20:01 | CTD survey completed. |
| | 20:10 | Lavrentyev left Junction of LFZ area, and sailed for Region No.4. |
| | 22:30 | Lavrentyev arrived at Region No.4, and Geophysical survey started. |

Aug 20 Sat 06:00 Cloudy but calm.

08:00 OM (AO, HS, YJ, JH, BB, AS, AD and NN). Weather seems OK. Flare No.65 was selected for coring. Schedule for CTD survey for methane anormaly, Sparker survey for flare line, Oceanographic coring and additional Sparker survey at Study Area No.2 were adjusted.

09:39 LV56-25HC core was retrieved at a flare No.65 (53º21.421'N, 144º30.167'E, 723 mWD). The core length was 510 cm including 30 cm of top portion. No GH observed. A dropstone at a core depth of 235 cm. Top 295 cm is Holocene layers and the deeper part is Pleistocene layers.

09:43 CTD survey was conducted (LV56-26CTD).

10:25 CTD survey completed.

11:39 LV56-27HC core was retrieved from a center of depression in Region No.4 (53º21.937'N, 144º31.983'E, 785 mWD). The core length was 533 cm including 8 cm of core catcher portion. No GH observed. Just after the core extraction from the bottom, several rising bubbles appeared probably from the cored hole. In about 15 minutes after the extraction, a clear image of gas flare appeared and increased the height with time at the same speed of rising bubbles.

11:35 CTD survey was conducted (LV56-28CTD).

12:07 CTD survey completed.

13:09 LV56-29HC core was retrieved from Flare No.65-1 close to LV56-25 coring site (53º21.406'N, 144º30.169'E, 723 mWD). The core length was 543 cm including 47 cm of top portion and 8 cm of core catcher portion. Sea bottom portion (30 cm long) missed. This core covers submarine depth from 30 cm to 573 cm. No GH observed. Gas cracks below a submarine depth of 360 cm. Water space observed at submarine depths of 520 cm (5 x 10 cm) and 550 cm (2 x 5 cm).

13:14 CTD survey was conducted (LV56-30CTD).

13:45 CTD survey completed. Lavrentyev moved to Flare No.21-1 in Region No.5.

16:00 LV56-31HC core was retrieved from a site close to LV56-05HC core (53º22.664'N, 144º25.420'E, 625 mWD). The core length was 413 cm including 10 cm of core catcher portion. No GH observed. For a core depth interval between 220 and 320 cm, watery surface, cracking noises and shell fragments covered with carbonate were observed possibly caused by dissociation of small GH crystals. Dryer surfaces of the core were observed outside of the above interval.

| | | |
|---|---|---|
| | 16:13 | CTD survey was conducted (LV56-30CTD). |
| | 16:44 | CTD survey completed. |
| | 16:52 | A CTD survey (31CTD to 39 CTD) for Methane Anormaly study (to the West and Northern East line) started to be followed by Sparker survey along an equally-spaced-flare line from North to South. |
| | 22:53 | CTD survey completed. |
| | 23:00 | Lavrentyev moved to Sparker line. |
| Aug 21 Sun | 02:00 | Sparker Survey started between a site (53º29.856'N, 144º22.386’E) and another (53º46.989'N, 144º15.751’E). |
| | 06:00 | Cloudy but calm. Sparker Survey completed. Lavrentyev moved to Region No.10. |
| | 07:50 | OM (AO, HS, YJ, JH, BB, AS, AD and NN). Weather seems OK. Region No.10 was selected as coring site for Geological Analysis (KOPRI) and Reference (KIT and POI). |
| | 08:00 | Preparation of coring operation started for oceanographic core. |
| | 08:54 | LV56-41HC core was retrieved from a site between Region No.9 and 10 (53º30.958'N, 144º23.022'E, 650 mWD). The core length was 333 cm including 10 cm of core catcher portion. No GH observed. A dropstone at 40 cm depth. Carbonate accretion at 90, 150and 200 cm depth. Gas cracks observed below 170 cm depth. Holocene/Pleistocene boundary around 120 cm depth. |
| | 08:58 | CTD survey was conducted (LV56-40CTD). |
| | 09:28 | CTD survey completed. |
| | 09:36 | Lavrentyev left Region No.9/10 for Study Area No.2 (Sparker Survey). |
| | 11:52 | Lavrentyev sailed toward south at 53º7.407'N, 144º34.426'E by 11.0 kts. |
| | 15:47 | Lavrentyev sailed toward south at 52º30.294'N, 145º4.330'E by 10.9 kts. |
| | 19:45 | Sparker survey started from East toward West in Study Area No.2. The survey direction should be turned to South at the West end. Cloudy but calm. |
| | 20:05 | Lavrentyev sailed toward West at 51º57.002'N, 145º39.471'E by 5.4 kts. |
| Aug 22 Mon | 05:10 | Sparker Survey finished. Lavrentyev left Study Area No.2. for Terpeniya Ridge. No flare was observed during the survey. |
| | 05:35 | Lavrentyev sailed toward South at 51º31.771'N, 144º53.130'E by 10.6 kts. |
| | 06:30 | Partly cloudy but calm. |
| | 09:00 | OM (AO, HS, YJ, JH, BB, AS, AD and NN). Weather seems OK. Terpeniya survey plan was discussed. Contents of Cruise Report of SSGH-11 were discussed. |

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| | 15:24 | Lavrentyev sailed toward South at 49º59.290'N, 145º41.295'E by 10.0 kts. |
| | 17:39 | Lavrentyev sailed toward South at 49º35.914'N, 145º39.471'E by 10.6 kts. |
| | 20:05 | Lavrentyev sailed toward South at 49º10.266'N, 145º37.192'E by 10.3 kts. Sunny. |
| Aug 23 Tue | 02:02 | Sparker survey started along the east coast of Terpeniya Ridge from north to south. |
| | 03:51 | Lavrentyev sailed toward South at 48º0.594'N, 145º32.000'E by 5.5 kts. Slightly Pitching/Rolling. |
| | 06:48 | Lavrentyev sailed toward South at 47º57.061'N, 145º32.012'E by 5.0 kts (1600 mWD). |
| | 07:20 | Lavrentyev changed sailing direction toward East (2200 mWD). |
| | 08:03 | Lavrentyev changed sailing direction toward North at 47º43.362'N, 145º40.100'E by 5.6 kts (2608 mWD). |
| | 09:00 | OM (AO, HS, YJ, JH, BB, AS, AD and NN). Weather seems OK. |
| | 10:10 | Lavrentyev changed sailing direction toward West. |
| | 12:30 | Sparker survey completed. Lavrentyev started 700 m survey (HA and BS along the eastern coast line of Terpeniya Ridge at 700 mWD). |
| | 15:58 | A flare was observed at continental shelf break (47º42.136'N, 145º21.048'E; f89; 227 mWD). |
| | 17:05 | 700 m survey completed and Sparker survey started from T108 toward SW (West of Terpeniya Rise). |
| | 19:42 | Sparker survey changed the direction to West. |
| | 22:00 | Sparker survey completed, and 700 m survey re-started along the western coast line of Terpeniya Ridge at 700 mWD. |
| Aug 24 Wed | 04:52 | The 700 m survey completed and Lavrentyev sailed to a flare site (f90-1 which is F196 last year) . |
| | 05:52 | LV56-42GR grab sample was retrieved from seabed at 47º40.421'N, 144º18.093'E, 211 mWD, f90-1 flare site). The grab did not close correctly. Almost empty (a little amount of sediment taken). |
| | 05:52 | CTD survey was conducted (LV56-43CTD). |
| | 06:10 | CTD survey completed. |
| | 06:28 | LV56-44GR grab sample was retrieved from seabed at 47º40.430'N, 144º18.089'E, 211 mWD, f90-1 flare site. Included are a worm, shell fragments, crusts and dropstones in the sediment. |
| | 07:05 | LV56-45HC core was retrieved from a flare site (f90-1) at 47º40.405'N, 144º18.099'E, 211 mWD. The core length was 173 cm including 3 cm of core |

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| | | catcher portion. No GH observed. The top 5 cm is Holocene layer, and includes carbonate concretion. Gas cracks below 100 cm depth. Pleistocene layer below 5 cm depth includes sand/turbidite layers. |
| | 07:15 | Lavrentyev moved for another flare site (f91 which is close to f213 last year). |
| | 09:45 | Lavrentyev arrived at the flare site. |
| | 10:47 | LV56-46GR grab sample was retrieved from seabed at 47º41.333'N, 144º47.990'E, 157 mWD, f91 flare site. Included are shell fragments and dropstones in the sediment. |
| | 10:49 | CTD survey was conducted (LV56-47CTD). |
| | 11:01 | CTD survey completed. |
| | 11:15 | Lavrentyev moved for a coring site (top of elongated mound). On the way, flare area (fs92; 163 mWD) and a flare (f93; 262 mWD) were observed. |
| | 12:46 | LV56-48HC core was retrieved from a flare site (f91) at 47º37.137'N, 144º45.650'E, 622 mWD. The core length was 383 cm including 1 cm of core catcher portion. No GH observed. The Holocene/Pleistocene boundary was not easy to recognize. A worm was observed at 17 cm depth, and worm holes were distributed through the entire core. Included are wood/shell fragments, sand layers and dropstones in the deeper part of the core. |
| | 12:47 | CTD survey was conducted (LV56-49CTD). |
| | 13:15 | CTD survey completed. |
| | 14:00 | Lavrentyev left the coring site and re-started 700 m survey. |
| | 17:00 | A Group photo was taken. |
| | 21:10 | A flare (f94, 550 mWD) had been observed about 4 nm North from Flare No.1. A plenary meeting was held. |
| | 22:30 | A flare (f95, 1060 mWD) had been observed about 20 nm South from Flare No.1. 700 m survey completed. Lavrentyev left for Port Korsakov. |
| Aug 25 Thu | 06:30 | Cloudy but calm. Warm. |
| | 07:50 | Lavrentyev sailed for Korsakov at 46º29.717'N, 142º45.976'E by 10.9 kts |
| | 08:55 | Lavrentyev arrived at Port Korsakov. |
| | 12:30 | KOPRI (Jin, Hong) members got off. |
| | 15:50 | Shelf-Flot picked up KIT cargo for Kitami. |
| | 16:00 | Customs Clearance finished. |
| Aug 26 Fri | 08:15 | KIT (Shoji, Minami, Hachikubo, Soramoto, Dewa) members got off. Lavrentyev left Korsakov for Vladivostok. |
| Aug 27 Sat | | Lavrentyev sailed for Vladivostok. |
| Aug 28 Sun | | Lavrentyev arrived at Port Vladivostok. |

## 4.2. List of Participants

| Institution | No. | Participants | Task |
|---|---|---|---|
| **KIT** | 1 | HITOSHI SHOJI | Co-Chief of Expedition |
| | 2 | HIROTSUGU MINAMI | Water Chemistry |
| | 3 | AKIHIRO HACHIKUBO | Gas Analysis |
| | 4 | HIRONOBU DEWA | Sediment Analysis |
| | 5 | YUSUKE SORAMOTO | Water Chemistry |
| | | | |
| **KOPRI** | 1 | YOUNG KEUN JIN | Co-Chief of Expedition |
| | 2 | JONG KUK HONG | Geophysics |
| | | | |
| **POI** | 1 | ANATOLY OBZHIROV | Chief of expedition |
| | 2 | NATALIYA NIKOLAEVA | Secretary, sedimentology |
| | 3 | ALEXANDER SALOMATIN | HA operation (head) |
| | 4 | BORIS LI | HA operation |
| | 5 | ALEXANDER DERKACHEV | Coring (head) |
| | 6 | GENNADY KRAYNIKOV | Coring |
| | 7 | ALEXANDER GRESOV | Coring |
| | 8 | MIKHAIL SAVENKO | Coring |
| | 9 | ALEXANDER KARNAUKHOV | Hydrology (head) |
| | 10 | VASILY BANNOV | Hydrology |
| | 11 | OLGA VERESHCHAGINA | Gas geochemistry |
| | 12 | ELENA KOROVITSKAYA | Gas geochemistry |
| | 13 | VLADIMIR PROKUDIN | Sparker (head) |
| | 14 | EVGENY SUKHOVEEV | Sparker |
| | 15 | ANDREY KOPTEV | Bathymetry |
| | 16 | OKSANA BELOUS | Helper for KIT |
| | 17 | ANDREY YATSUK | Helper for KIT |
| | 18 | ANNA MAR’YASH | Helper for KIT |
| | 19 | IRINA SALIENKO | Helper for KIT |
| | | | |
| **IO (Moscow)** | 1 | BORIS BARANOV | Geophysics |

## 4.3. Group Photo

Aug 24 Wed 17:03 (R/V Lavrentyev)