Preliminary Results of Marine Heat Flow Measurements in the Canadian Beaufort Sea and Its Implications for Intermittent Methane Fluid Expulsion

Young-Gyun Kim[1]*, Young Keun Jin[1], Jong Kuk Hong[1], Michael Riedel[2], Sang-Mook Lee[3]

[1]Korea Polar Research Institute, KIOST, Incheon, Republic of Korea
[2]Geological Survey of Canada-Pacific, BC, Canada
[3]Seoul National University, Seoul, Republic of Korea

*E-mail address: ygkim@kopri.re.kr

EGU2014-4814

European Geosciences Union
General Assembly 2014

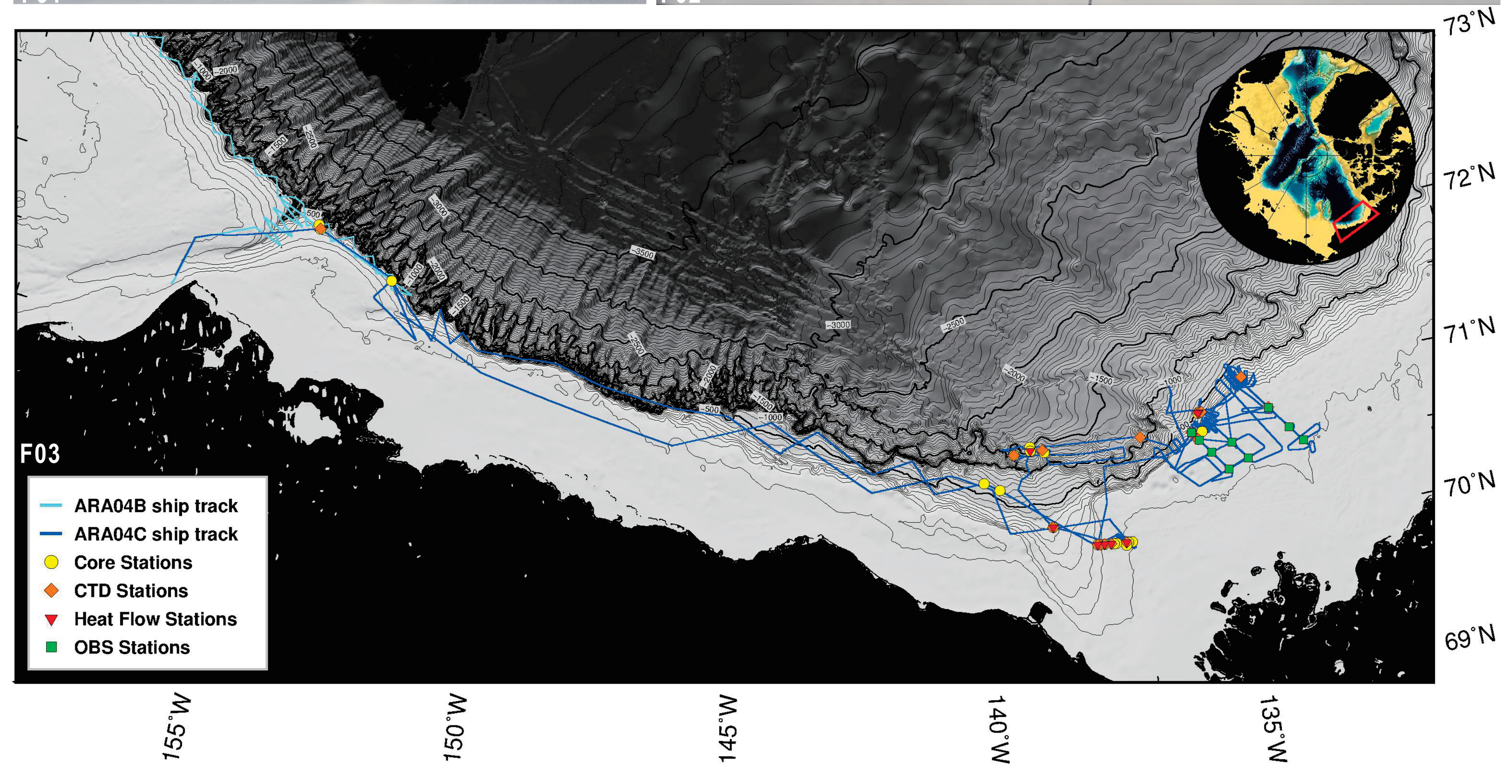
27 April - 02 May 2014

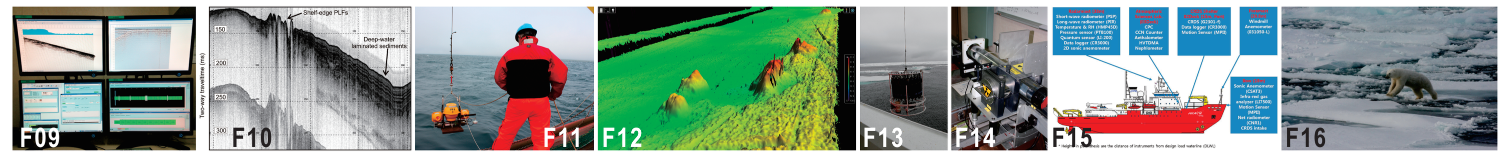
Austria Center Vienna
Vienna, Austria

Abstracts

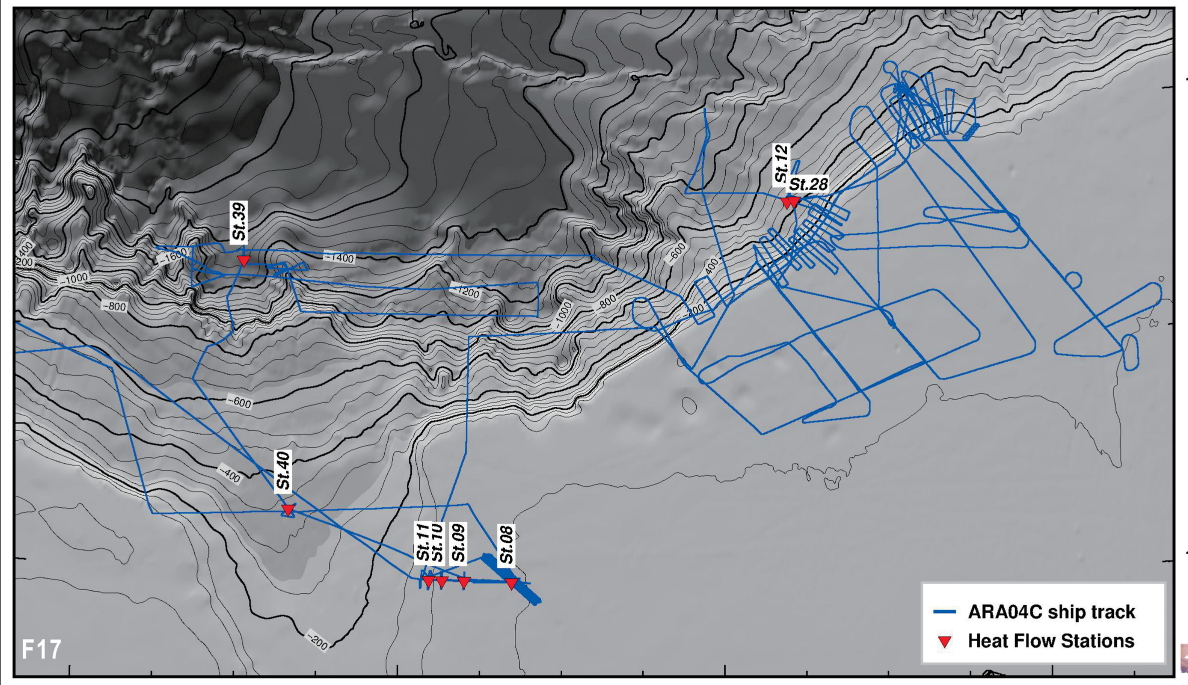
Marine heat flow measured at subsurface interval of a few meters using a heat probe is one of useful approaches to show the status of fluid circulation within the marine sediments, even though it can show only a snapshot of long-term variation caused by the fluid circulation. Expedition ARA04C using IBRV Araon was carried out in the Canadian Beaufort Sea during 6-24 September 2013 as Korea/Canada/USA international cooperative research. During the expedition, multidisciplinary programs including multichannel seismic survey, sediment coring, water sampling, atmospheric observation, and heat flow measurement were carried out over the continental shelf and slope area. In particular, Beaufort Shelf, one of regions experiencing fast ocean warming in the past several decades, shows characteristic features associated with degradation of permafrost reaching at the continental shelf. In this context, 8 sites for marine heat flow measurements were chosen: 1) in/outside of the flat-topped mud volcano located in the continental slope as one of fluid expulsion features, 2) along a transect line on the eastern slope of MacKenzie Trough where degradation of permafrost may occur, and 3) at a site closed to IODP pre-proposal #753 as reference. Unfortunately, attempts to measure in-situ thermal conductivity of sediments were failed due to instrument problem. Geothermal gradient observed on the mud volcano flat-top is much higher than ones from the reference site and outside of the volcano, indicating that there occur intermittent fluid expulsions restricted within the volcano. High methane concentration detected in bottom water column by 10 meters above the volcano top is indicative of methane fluid expulsion. Further detailed heat flow study in association with analysis of physical properties of sediment cores through all sites would increase our understanding of nature of methane expulsion emitted from sediments in linkage with degradation of permafrost over the arctic shelf.

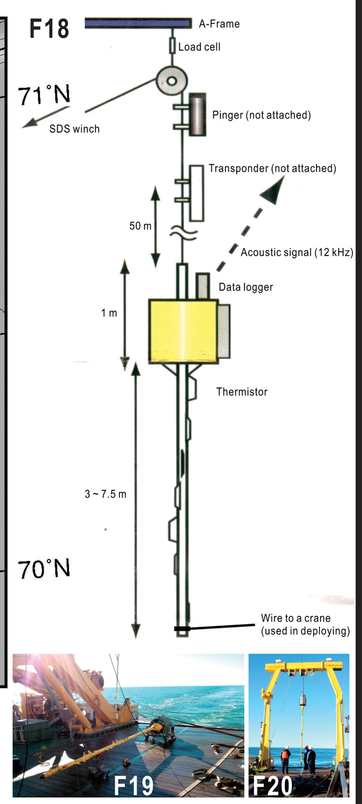
Expedition ARA04C (Arctic Araon Exp. 04 Leg C)

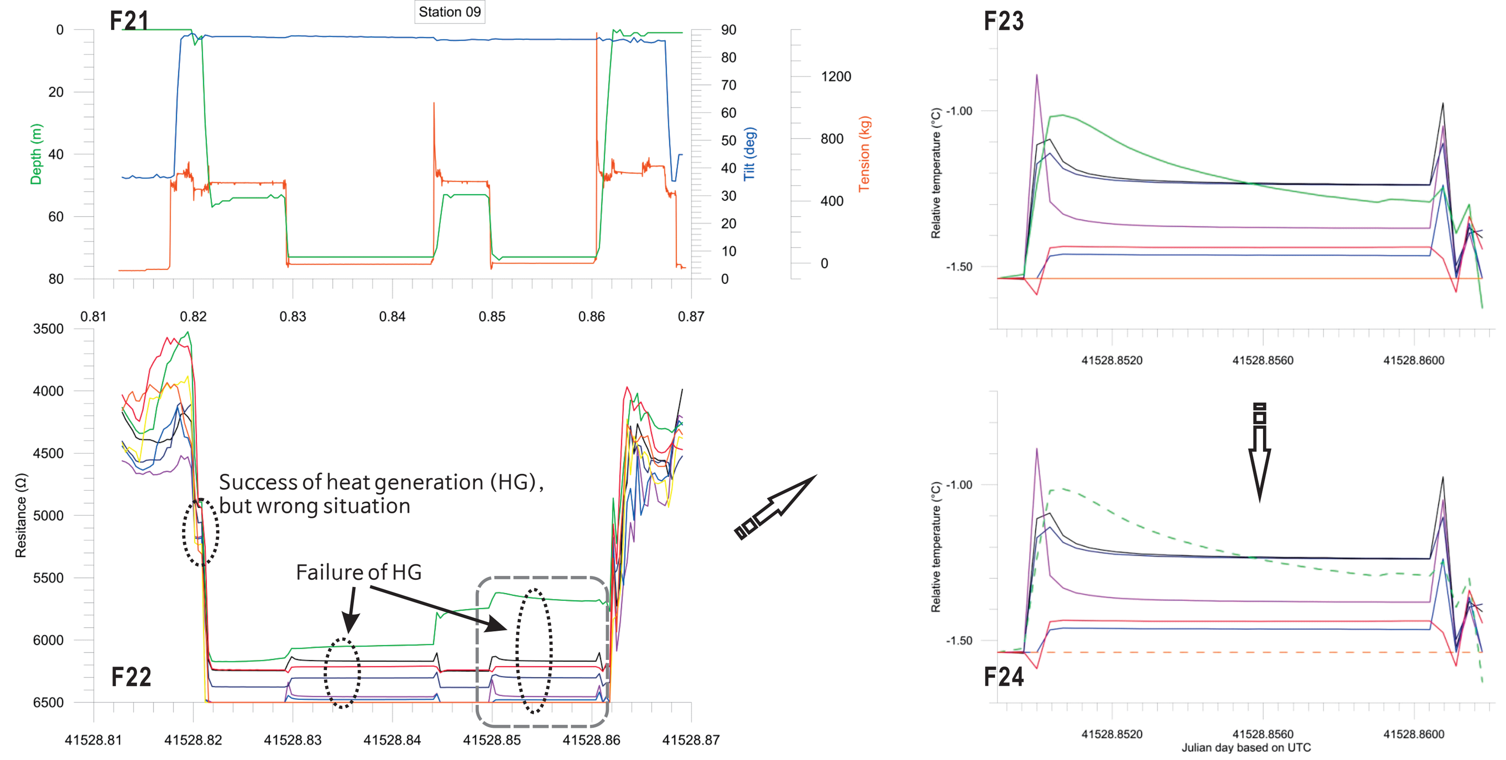




Marine Heat Flow Measurements

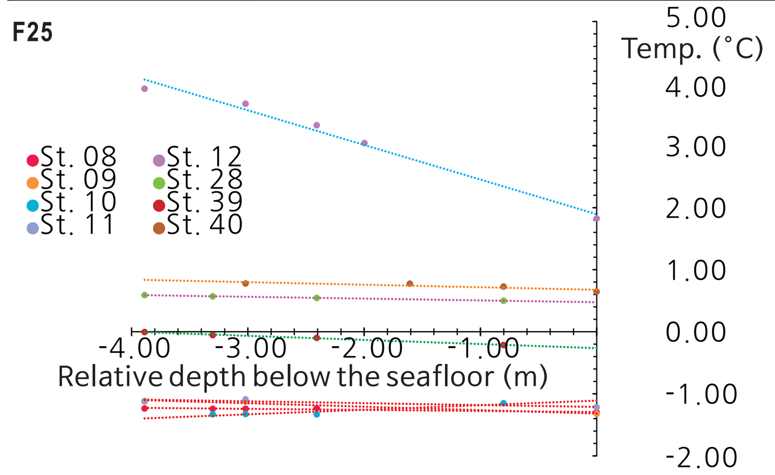


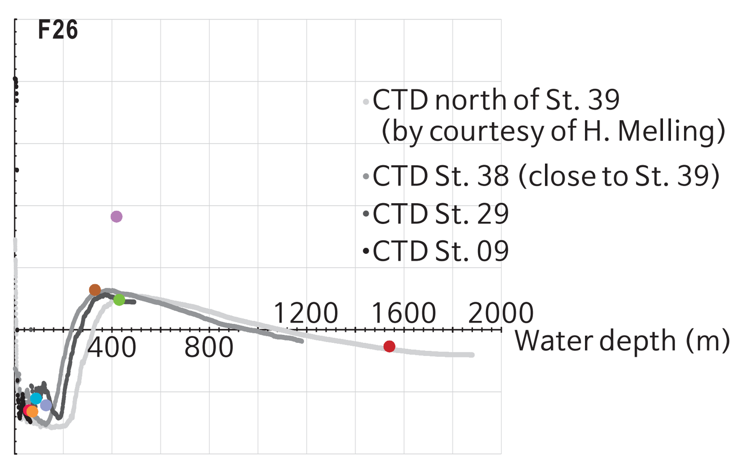


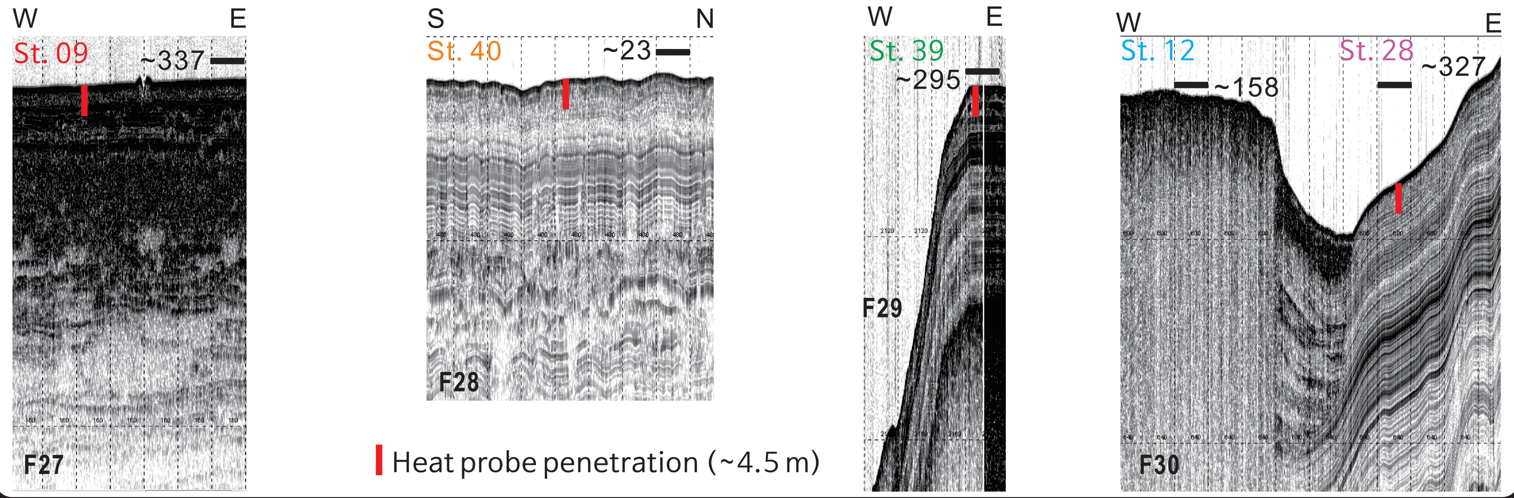


Observed Geothermal Gradient & Seafloor Temeperature

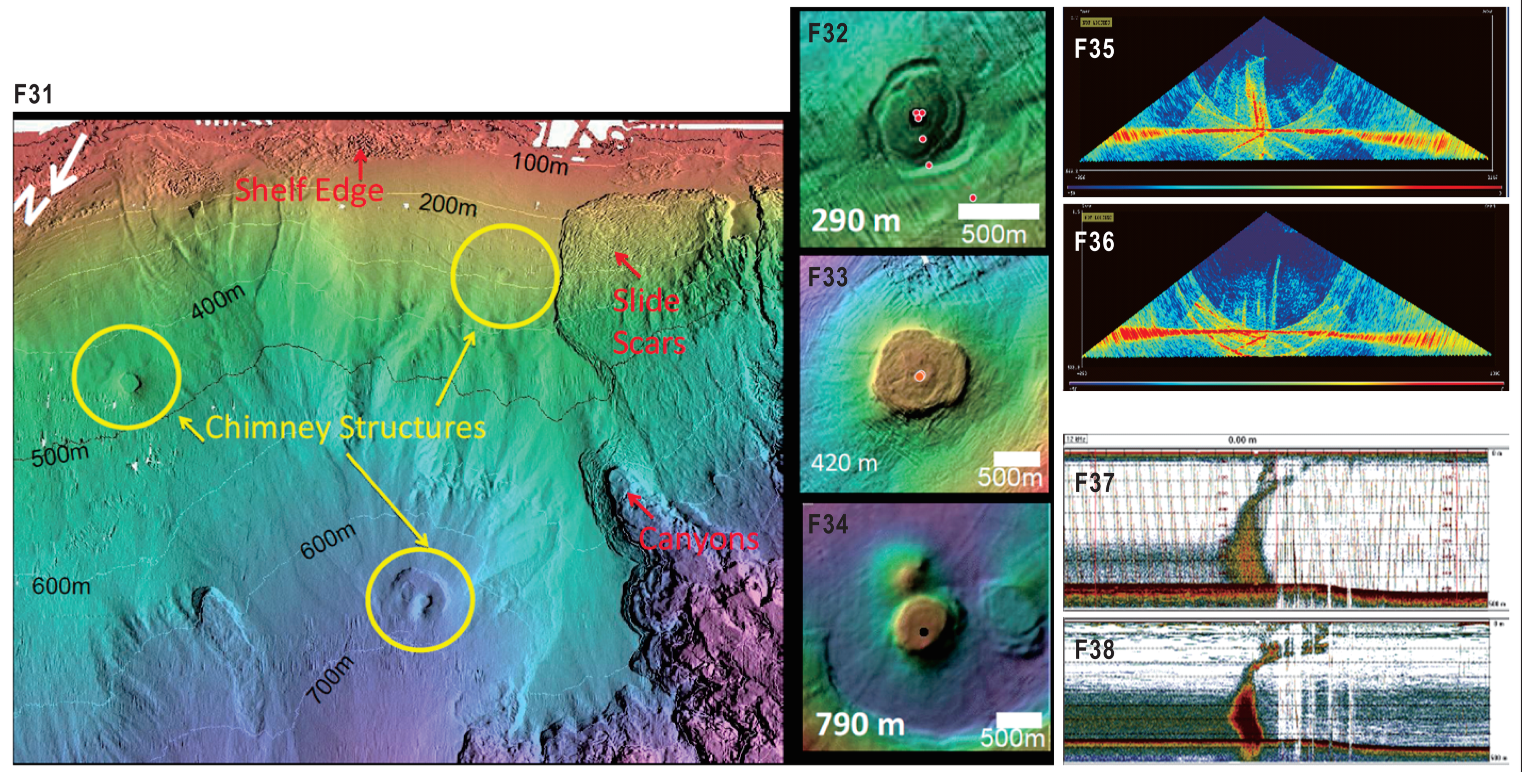
T01	St. 08	St. 09	St. 10	St. 11	St. 40	St. 39	St. 12	St. 28
Seafloor temp. (°C)	-1.30	-1.32	(-1.11)	(-1.22)	0.64	(-0.27)	1.82	(0.48)
Geothermal gradient (mK/m)	16.8	55.3	-73.9	30.1	41.5	66.1	557.9	28.9
Water depth (m)	59	73	88	129	330	1540	419	430
Site description	Eastern slope of the Mackenzie Trough (EMT); permafrost below the seafloor				EMT; No permafrost	Around IODP pre-proposal #753	Top of mud volcano	Outside of mud volcano

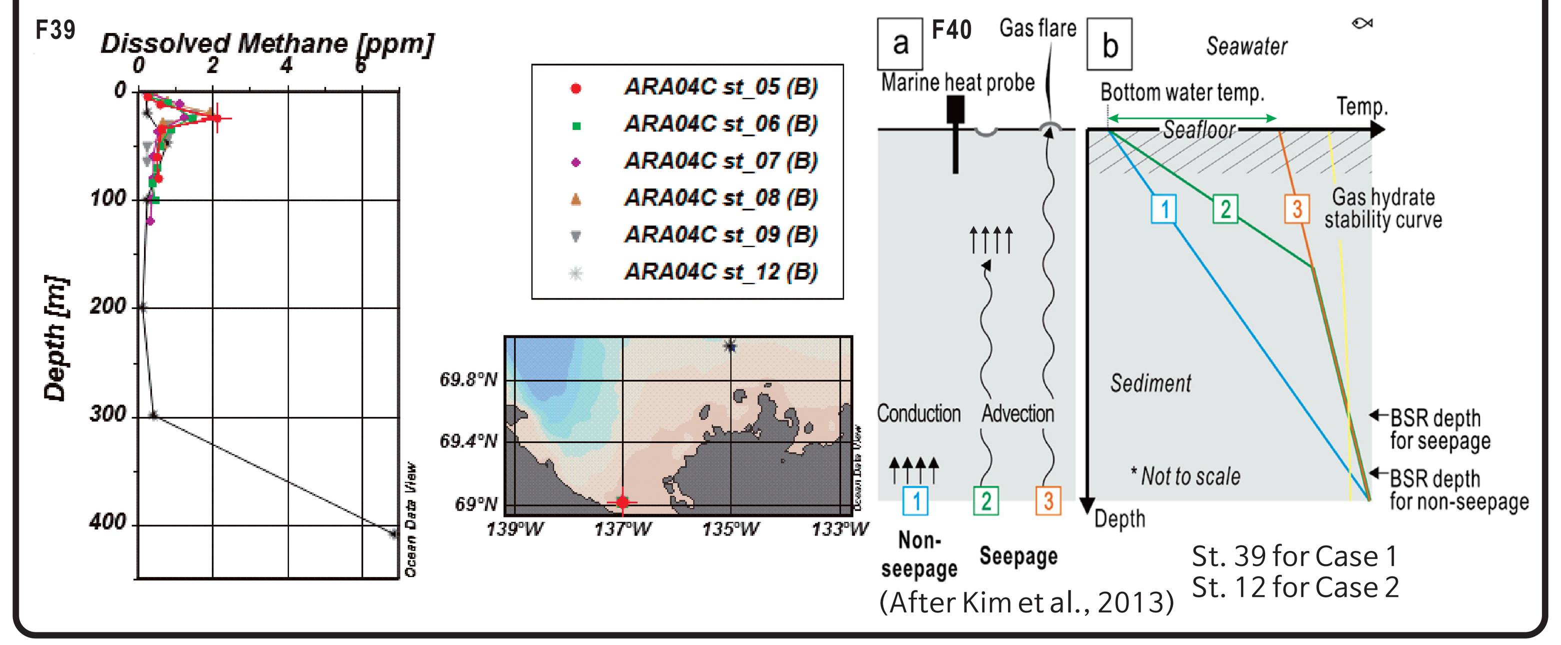






Intermittent Methane Fluid Expulsion from Mud Volcano at 420 mbsl





Conclusions & Future Plan

- Marine heat flow in the Arctic Sea is observable with the current marine heat probe but it is necessary to modify for better results.
- In the research area, geothermal gradient is observed as a range between -73.9 mK/m and 557.9 mK. Linear temperature profile together with seafloor temperture equilibrated to the surrounding water except at Station 12 (top of mud volcano) indicates the steady state in conductive heat transfer mode within sediments. Wide range from the Eastern Mackenzie Trough seems to stem from effect of permafrost (ice).
- At Station 12, warm methane-rich fluid is intermittently emitted from sediments into the water column. Further, origin depth and flux of the fluid will be analyzed with utilizing porewater chemistry and physical properties of sediment cores.
- Background geothermal gradient seems to be measured from Station 39, the deepest site, but we need check out during the upcoming cruise in this summer. At this stage, we may consider using Tishchenko et al. (2005)'s equation that the top of gas hydrate stability zone locates ~320 mbsl.
- In-sith thermal conductivity is not measured due to instrument problem. In the upcoming cruise, additional thermal conductivity meter (TK04 with a need probe) will be prepared to measure laboratory thermal conductivity of sediment cores on board.

References

- Jin and Riedel, 2014. ARA04C Cruise Report, Korea Polar Research Institute, 174 pages (not published).
- Kim et al., 2013. The Stability of gas hydrate field in the northeastern continental slope of Sakhalin Island, Sea of Okhotsk, as inferred from analysis of heat flow data and its implications for slope failures, Marine and Petroleum Geology, 45: 198-207.
- Tishchenko et al., 2005. Calculation of the stability and solubility of methane hydrate in seawater, Chemical Geology, 219: 37-52.

Acknowledgments & Notice

- This research was supported by Korea Polar Research Institute (PE14061 and PM13020). The heat probe is a property of Seoul National University (Prof. Sang-Mook Lee). We thank the captain and crew of the IBRV Araon, and all participants of the Expedition ARA04C.
- The contents in this poster are going to be presented again in "20th International Symposium on Polar Sciences" on 27-29 May, 2014 at Korea Polar Research Institute, Incheon, South Korea.

F01. The Arctic Araon Expedition 04 Leg C (ARA04C) as an international cooperative research, carried in the Canadian Beaufort Sea in 2013.
F02. Participants of the Exp. ARA04C. Orange boxes for co-chief scientists.
F03. Ship track and stations during the Exp. ARA04C.
F04. View from back of Control Deck. Ice conditions during the Exp. ARA04C are not favorable for multi-channel seismic survey.
F05. View of Back Deck. Numerous instruments are seen.
F06. Gravity corer.
F07. Multi-unit corer.
F08. Wet laboratory.
F09. Operation of multi-channel seismic survey in Dry Laboratory.
F10. Result of subbottom profiling survey using hull-moundted SBP120.
F11. Deployment of Ocean Bottom Seismometer provided by Canadian side.
F12. Result of multibeam survey using hull-mounted Em122. Pingo-like structures in the Gary Knolls area.
F13. Rosset system consisted of Conductivity-Temperature-Depth, Nansen bottles, and Methane sensor.
F14. Multi-seonsor Core Logger provided by Alfred Wegener Institute.
F15. Overview of atmospheric observations.
F16. Polar bear seen during the Exp. ARA04C.
F17. Eight stations for marine heat flow measurements.
F18. Schematic diagram of a Lister-type heat probe provided Seoul National University. Five channels only for temperature measurement, three ones for temp. measurments as well as heat generation. Adjustable weight and length but set into 4.5 m-long barrel and 450 kg in total.
F19. Lister-type heat probe.
F20. Deployment of the heat probe.
F21. Situation information during heat flow measurement at Station 09. Depth and tilt information from a data logger in the heat probe. Tension from a ship winch.
F22. Raw data of heat flow measurement at Station 09. Resistance from 8 channels with time.
F23. Expanded view of dashed square area in F22. Resistance data are corrected.
F24. Screened data from F22. Conversion to temperature is applicapble. Dashed lines showing abnormal response are ruled out in conversion process.
T01. Observed geothermal gradient and seafloor temperature. Highest value of geothermal gradient from the top of mud volcano. Wide range of geotheral gradient from Eastern Mackenzie Trough.
F25. Observed temperature within sediments with relative depth below the seafloor.
F26. Observed seafloor temperature and water temperature profiles from CTD. Only at Station 09 (top of mud volcano), seafloor temperature is not equilibrated to, much higher than, that of the surrounding water.
F27 & F28 & F29 & F30. Results of subbottom profiling survey at stations 09, 40, 39, 12, and 28. Ice below the seafloor at Station 09, well laminated layers at station 40, and 39, and acoustic wipe-out below the top of mud volcano at Station 28 are characterized for each distinct area.
F31. Detailed bathymetry of three mud volcanos located in the study area.
F32 & F33 & F34. Mud volcanos at water depth 290 m (called as the Coke Cap), water depth 420 m (observed during the Exp. ARA04C: Station 12), and at water depth 790 m.
F35 & F36. Results of multibeam survey at mud volcano at 420 mbsl. Fluid expulsion features varying with time are seen.
F37 & F38. Results of echo sounder using 12 kHz above and 38 kHz below. Fluid explusion feature is seen.
F39. High methane concentration of the seawater at Station 12, indicating that emitted fluid contains rich methane.
F40. Higher geothermal gradient from the seepage by intermittent fluid expulsion. Geothermal gradient from Station 12 is much higher than that from Station 39 considered as the background geothermal gradient.