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Source characterization and temporal variation of methane seepage from thermokarst lakes on the Alaska North Slope in response to Arctic climate change

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University of Alaska
Fairbanks, AK 99775

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Contributors:

Matthew J. Wooller and Katey Anthony Walter
Institute of Northern Engineering
University of Alaska Fairbanks
Fairbanks, Alaska 99775
Phone: (907) 474 6738
Email: ffmjw@uaf.edu

Mary Beth Leigh and Ruo He
Institute of Arctic Biology
University of Alaska Fairbanks
902 N. Koyukuk Dr.
Fairbanks, AK 99775-7000
Phone: (907) 474-6656
Email: mb.leigh@uaf.edu

Carolyn Ruppel and John Pohlman
US Geological Survey
Woods Hole Science Center
Woods Hole, MA 02543
Phone: 508-457-2330
Email: cruppel@usgs.gov

Monica Heintz,
Department of Earth Sciences, UCSB, CA.
Phone: 805-893-3036

Prepared for

U.S. Department of Energy - NETL
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26508

Summary

The goals of this research are to characterize the source, magnitude and temporal variability of methane seepage from two representative thermokarst lake areas within the Alaskan North Slope gas hydrate province, assess the vulnerability of these areas to ongoing and future Arctic climate change and determine if gas hydrate dissociation resulting from permafrost melting is contributing to the current lake emissions.

This report includes two components: Section 1) A report on the July fieldwork activities and Section 2) A quarterly progress report. Work during the final quarter of this project period has focused on conducting the group's analyzes of samples collected during the previous fieldwork. Information for the quarterly report (section 2) is presented relative to project tasks and the lead investigator responsible for each task.

1) Summer 2009 Field report. July 2009

The primary objective of the July 2009 fieldwork was to acquire the samples and data for Tasks 5-7 during Phase II of the project. These included acquisition of samples of lake sediment to conduct stable isotope probing (Task 7) and gas analyses and flux measurements (Task 5). A primary objective also included conducting geophysical surveys at our study sites. In addition the fieldwork was to support the collection of water samples for Monica Heintz to conduct methane oxidation rate measurements at our study sites and to allow seasonal comparisons. Details related to these specific areas are described below.

Wooller (UAF) and Ruppel (USGS) were primarily responsible for the extensive logistics for the July fieldwork. Access to Lake Qualluraaq via the dominant mode of transportation (All-Terrain-Vehicles rented from inhabitants of Atqasuk) would have not been possible without the guidance and support of local inhabitants of Atqasuk and the use of traditional routes. Critical advice and assistance came from Doug Whiteman, Mel Wong, Kimberlee Brent, Thomas Itta and Wanda Kippi in Atqasuk. Group outreach included Wooller attending a monthly (July 09) community council meeting in Atqasuk to present three posters about the group's work and approach. Mel Wong at Meade River School organized space at the school to accommodate our scientific group, which included a classroom that was temporarily adapted to create a laboratory space for our work. Considerable support was given by all those working at the school. Wooller and Ben Gaglioti's (UAF graduate student) roles were primarily support of others researchers' activities (assistance with water sampling, logistics, transportation, coring) at Lake Qualluraaq and others sites during the fieldwork. Samples of modern chironomids were collected from the field sites for stable isotope analysis. Coring at the sites used a percussion coring system with a brass head (modified design created by Wooller based on original plastic coring head designs supplied by Aquatic Research. The modified brass design was made by Aquatic Research and subsequently modified by the engineering workshop in the Institute of Northern Engineering, UAF). Virtually all of the coring that took place in both the May and July fieldwork utilized this system. This coring system was specifically designed for this project to accommodate the challenging coring (mixed lithology) in thermokarst lakes. Additional detailed discussions about coring procedures and equipment took place prior to the May field work between Wooller (UAF), Gaglioti (UAF), Pohlman (USGS), Katey Anthony Walter (UAF), Andrea Krumhardt (UAF) and Dr. Nancy Bigelow (UAF). Wooller (UAF), He (UAF) and Leigh (UAF) all participated and passed a bear encounter and shot gun training class (29 June 2009) in preparation for the summer fieldwork.

Pohlman (USGS) lead coring operations during the July field campaign with assistance from other team members (notably Ben Gaglioti). Coring was conducted from a floating platform consisting of two inflatable rafts strapped to a 1 x 3 m plywood platform mounted on two aluminum beams. The platform was positioned on the coring site by floating downwind toward the predetermined core site and guiding the raft with an attached inflatable kayak. Once the platform was in approximate coring location, a 10 lb anchor was deployed. To moor the platform in a stable position, 3 additional anchors were deployed off each corner of the platform. With the anchors in place, the lines were tightened and the platform was sufficiently stable for coring. During the July 2009 fieldwork at Lakes Qualluraaq and Killarney, 7 sediment coring sites were visited – 4 at Lake Qualluraaq and 3 at Lake Killarney. Two short push cores (~15-20 cm long) were carefully collected at each coring location and sectioned at 1-2 cm intervals for methane oxidation incubations and stable isotope probing experiments. The overlying water from these dedicated microbiology cores was collected with a syringe and store in 50 ml Falcon tubes for incubation experiments. Another short push core was collected and processed on site to collect pore water samples at a vertical resolution of ~2 cm. After transporting the cores back to the laboratory, the cores were sectioned at 2 cm intervals and preserved for solid phase and biomarker analysis. The site and sample information for each of the near-surface high-resolution cores is provided in Table 1. A fourth core was taken at each site with the percussion coring system. These were sealed, labeled and transported back to the lab where they were subjected to pore water extraction and then sectioned for organic geochemical and microbiological treatment/analysis. See Table 1 for site and sample information from each core. Given the complexity of positioning the platform and acquiring the cores, 1 core was collected each day at Lake Qualluraaq and 1-2 cores were collected each day at Lake Killarney. The pore water and sediment samples were collected in vials and containers appropriate for specified analyses.

Mary Beth Leigh (UAF) and Ruo He (UAF) collected water and sediment samples from Qualluraaq Lake and Killarney Lake for microbial analysis. Four sites (Table 1) were sampled from Qualluraaq Lake. Three sites (Table 1) were sampled from Killarney Lake. Water samples of approximately one liter each were taken from the top, middle and bottom depths at each sampling site. Water temperature, dissolved oxygen and pH at different sampling depths at each site were measured *in situ* using a YSI meter. Core samples (described above) were used for the collection of sediment and sediment-water interface microbial samples. Holes were drilled in freshly extracted cores to collect water within 1 cm at the top of sediment-water interface. After cores were split, sediment samples were collected every 2 cm from the top 15 cm sediment and then every 5 cm for the remaining length of the core. The sediment samples were immediately placed in a plastic freezer bags, which were closed and all free air were removed. Samples were homogenized in the bag and then a subsample was frozen for direct molecular studies. Sediment samples in the plastic bags were kept at 4 ^{o}C for methane oxidation incubations and stable isotope probing (SIP) experiments.

Monica Heintz (UCSB) collected water samples for determination of dissolved methane concentration, methane oxidation rate and stable isotopic composition of methane at 12 stations on Lake Q. All stations were occupied during a 6-hour period July 13-14, 2009. A thunderstorm passed over the lake just before the first station was sampled and strong winds created whitecap waves. Hydrographic data was collected concurrently with sampling and confirms a well-mixed water column. Thus, a single sampling depth was chosen, 0.5 m from the sediment surface. Water samples were also collected and filtered for DNA and lipid extraction at 3 stations: LQ-seep, LQ-west and LQ-CM. These samples will serve to identify members of the microbial community who are responsible for methane consumption within the water column. Results from lipid sample analysis will also serve as a reference for sediment biomarker studies. Methane concentration, oxidation rate and stable isotope samples and DNA samples were also collected at two nearby lakes, Coffee Lake and Terrapin Station. In each of these lakes water was collected at a single depth (0.5m from sediment surface) at a single station, at the same locations sampled during the May trip. Two additional lakes in the Fairbanks area, Lake Killarney and Goldstream Lake, were sampled on July 16-17, 2009. Three stations on Lake Killarney and four stations on Goldstream Lake were sampled at three depths, 0.5 m from the bottom, 1 m from the surface and 20 cm from the surface. Station locations were chosen to coincide with bubble traps set up by Dr. Katey Anthony Walter's group and with locations where cores were collected both in May and July. Two of the stations on Goldstream Lake were also sampled for water column methane concentrations and oxidation rates in May.

Carolyn Ruppel (USGS) conducted extensive geophysical surveys on Lake Qualluraaq in July 2009 with the goals of mapping lake bottom stratigraphy, imaging the structures associated with the seep, locating other lakebed features possibly associated with gas charging/gas emissions, and constraining the thickness of the thaw bulb. The surveys were conducted from a motorized, 10' inflatable boat (*R/V Tundra*), with most instrumentation towed behind the boat and all navigation recorded by real-time GPS. Due to the distance between Lake Qualluraaq and the most proximal GPS base station in Atqasuk, we were unable to post-process the kinematic GPS data to obtain higher accuracy. Still, our experience was that we were rarely on WAAS during the surveys, meaning that the real-time GPS data were still reasonably accurate (within a few meters). Deployment techniques for geophysical instruments that are usually used in marine environments were changed and adapted for use in the shallow water of Lake Qualluraaq.

The suite of geophysical instrumentation deployed on Lake Qualluraaq was designed to provide redundancy and different types of information about subbottom features based on the disparate propagation characteristics of acoustic (Chirp) and radar (ground penetrating radar) waves and direct electrical current (continuous resistivity profiling) through water, gas-charged water and sediments, permafrost/ice wedges, and lake bottom sediments. Chirp data were collected with the Edgetech 424 fish towed below floats near the water's surface. The manufacturer provided special tuning to enable data acquisition in shallow water at 4-24 kHz swept frequency with 4 ms sampling rate. Ground penetrating radar imagery was acquired with a unshielded 50 MHz remote terrain antenna (RTA) that we sheathed in Flut borehole liner material to protect the battery contacts from being flooded. The RTA can be deployed in the U.S. only by U.S. government entities, and we were fortunate to have it available for this project. The RTA configuration has the transmitter-receiver inline, instead of in the more typical bistatic arrangement. This renders the RTA a powerful tool for rapidly imaging large areas or along long profiles. To the best of our knowledge, the GPR data collected on Lake Q represent the first ever water-towed GPR RTA deployment by the Geologic Division of the USGS. Continuous resistivity profiling (CRP) was conducted using both short (2 m electrode spacing) and long (5 m electrode spacing) streamers. These surveys can respectively provide shallow, higher resolution imagery and deeper, lower resolution imagery of sublake electrical conductivity structure. Additional instrumentation included a fishfinder with internal GPS, which was used to acquire side-looking sonar images of the lake bottom and high-frequency images of gas in the water column.

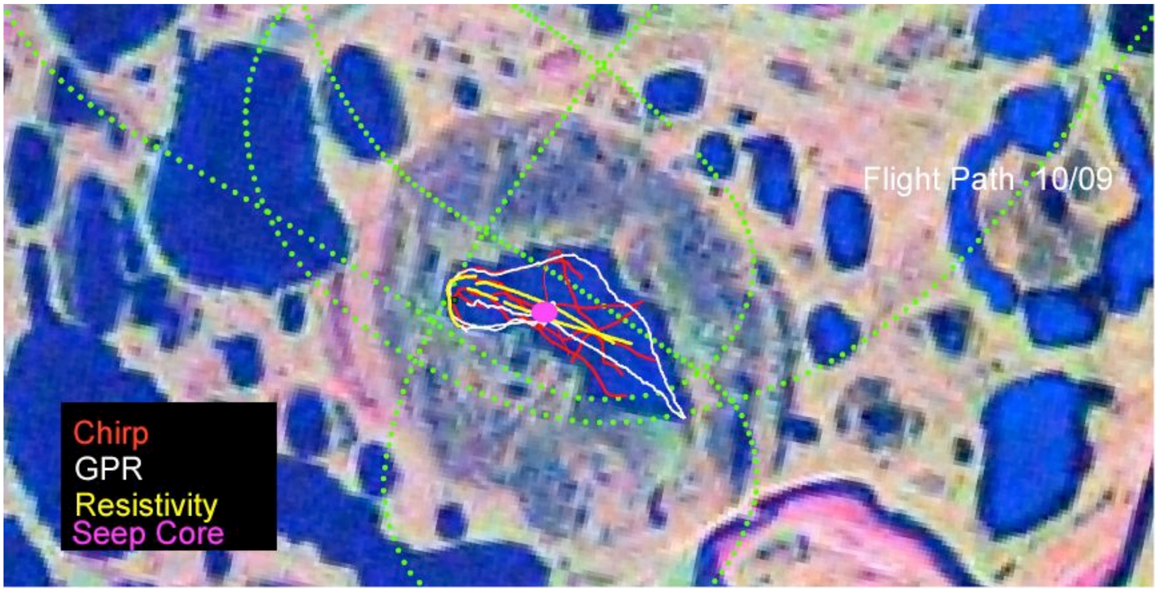

Figure 1 (Ruppel): The locations of Chirp (red), GPR (white), and long streamer CRP surveys (yellow) conducted on Lake Qualluraaq. To reduce image clutter, short streamer CRP surveys are not shown.

Due to time constraints, the weight of the equipment, and other logistical challenges, acquisition of geophysical data on the tundra surrounding Lake Qualluraaq could not be accomplished in July 2009, although the USGS had, as a precaution, shipped to Atqasuk the necessary equipment to make such surveys possible had their been sufficient time. Even without the land-based data acquisition, the geophysics program on Lake Qualluraaq could not have been completed without floatplane support provided by a colleague from the USGS Alaska Science Center, who had his pilot ferry some of the heaviest equipment between Atqasuk and Lake Qualluraaq.

The small size of Killarney Lake and the presence of instrumentation installed at the site for other UAF projects made towing geophysical equipment extremely challenging. We were able to acquire minimal Chirp imagery of the lake bottom and a few fishfinder screenshots. We attempted GPR data acquisition for several hours. In the end, the high-organic content of the water in Killarney Lake so attenuated the radar signal that we had to abandon the effort. It is noteworthy that the GPR data from Killarney were so poor that colleagues who reviewed the data at first believed the GPR data were being acquired in a seawater setting. Geophysics data acquisition was more successful on Smith Lake, a larger thermokarsting lake close to the UAF campus. There, the water quality was good enough to produce some useful GPR imagery. Deployment of the Chirp fish was logistically difficult in muskeg conditions at the edge of the lake, but it was eventually possible to survey most of this lake, where we noted frequent signs of escaping gas in small bubble streams.

2) Quarterly progress report

Task 5.0 - Constraining migration paths. Carolyn Ruppel (USGS): Since the completion of summer field research, the USGS has extracted navigational data from the Chirp files and generated raw bitmap images. Stacking and other simple processing is being completed by a member of the USGS technical staff and will not be finished until late November 2009. The most interesting aspect of the raw Chirp imagery is the lack of acoustic transparency beneath the seep site, implying that the sediments beneath the pockmark are not particularly gas-charged. The lake bottom was indurated enough that the Chirp signals did not penetrate to the base of the thaw bulb. GPR data have been ported into a commercial 2D analysis code and basic processing has commenced. Interpretation of GPR data can be challenging in sediments with gas charge, as gas can cause radar attenuation or lead to stronger reflectivity, depending on the impact of gas on the relative water content of the sediments. The radar returns from beneath the seep at Lake Qualluraaq confirms these complex relationships. Radar penetration provided better imagery of the lake bottom sediments in Lake Qualluraaq than did the Chirp data though. CRP data are typically inverted with 2D FEM-based codes, but the experience of colleagues who have worked on similar thermokarst lake data sets has shown that 1D inversions are better able to capture the high heterogeneity in lateral structure. 2D quick-look inversions conducted to date have highlighted the occurrence of ice wedges and revealed provocative patterns of low and high conductivity within the sediments at and near the seep site. The fishfinder images of the lake-bottom pockmark associated with the seep and methane in the water column near the seep have been used in both DOE and USGS publications about the project. Note that all data acquired for this project are subject to normal USGS data management procedures and activity reporting, with set timelines for archiving and internal reporting on data processing.

For most of the time between the completion of July fieldwork and mid-October, Ruppel's activity on this project focused not on analysis of the geophysical data, but rather on planning and managing aerial surveys for location of seeps in just-frozen lakes on the Alaskan North Slope, using the approach long advanced by Katey Walter Anthony. Ruppel built an extensive GIS using both public and non-public data sets, lined up professional photographic support from the USGS and garnered advice on oblique aerial photography from the 3 USGS groups most experienced in conducting such surveys, contacted numerous government and other researchers for access to unpublished information, wrote an extensive Project Aviation Safety Plan required by the US Dept of Interior and completed required aviation training, contracted aircraft through the DOI Aviation Services office, arranged for required flight following by Alaska Interagency Aviation personnel, discussed flight plans with a native community representative and the Arctic Office at BLM to ensure lack of interference with subsistence activities, and determined flight paths that avoided Class E airspace.

The initial attempt to conduct the overflights was made out of Deadhorse starting ~14 October. Unfortunately, the chartered single-engine aircraft was stuck 1500 km south of Deadhorse, unable to take off due to a flooded runway. The central North Slope also experienced record high temperatures during that period, resulting in puddles and cracks forming in the new ice on the lakes, which had to be frozen for the survey technique to work. The warm weather also produced extensive coastal fog and very low ceilings for days at a time. The ceilings were far too low for the overflights or even for having the aircraft come over the Brooks Range from SE Alaska using visual flight rules.

During a second attempt to fly the surveys, about a week later, we chartered a larger single-engine aircraft capable of instrument flight out of Barrow and flew more than 800 miles on the Barrow peninsula, in known seep areas near Atqasuk, over features that had been identified as potential targets on the central North Slope, and over old USGS methane project survey lines and near Milne Point close to Prudhoe Bay on 22 and 23 October. Katey Walter Anthony, Ben Gaglioti, and Laura Oxtoby from UAF participated in these flights, as did Ruppel and a photographer C. Worley from the USGS. Fog at low levels prevented completion of the surveys as far east as Deadhorse, and restricted airspace near Kuparuk made it impossible to closely follow one of the old USGS ground methane survey lines. The ice/snow conditions for these aerial surveys were generally good. The surveys followed a period of blizzard and very high winds that had almost completely removed the snow from some Prudhoe-area lakes, leaving behind black ice. Conditions were better in all other surveyed areas, but it is possible that some of the secondary seeps (e.g., sites less ebullient than the Lake Qualluraaq primary seep) may have already been frozen over according to independent information provided by Katey Walter Anthony. Large numbers of high-resolution, GPS-tagged images were acquired during these surveys. Full navigation was recorded by handheld GPS units, and the flight path for 23 October was fed directly into Ruppel's GIS for real-time plotting on target features across a wide swath of the North Slope. In accordance with USGS policy, photos and navigation files acquired by USGS personnel are being appropriately archived and documented.

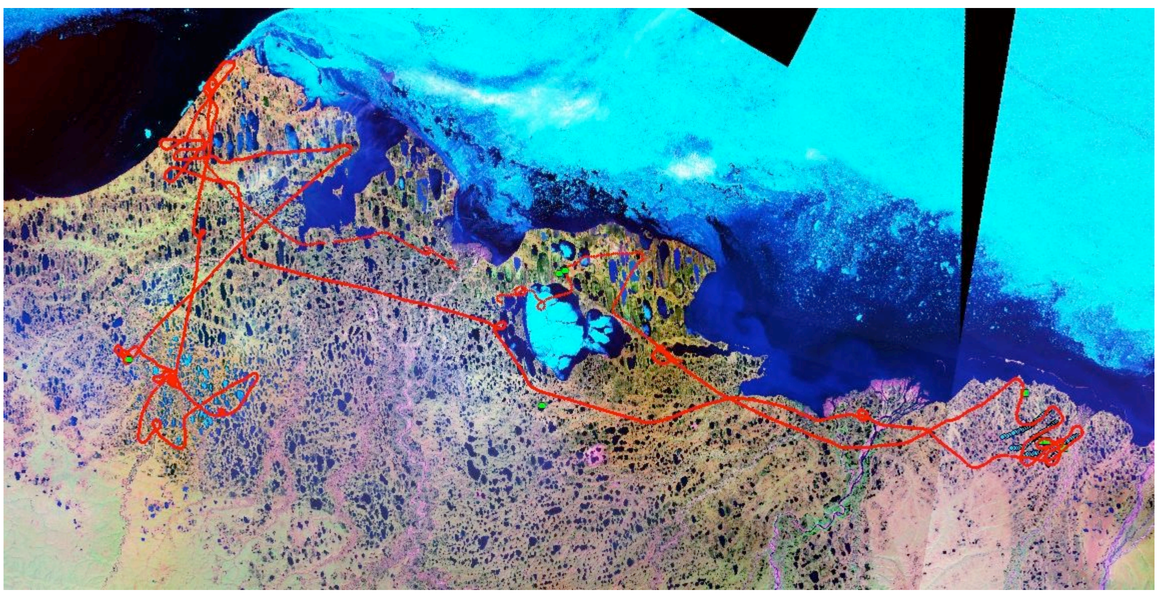

Figure 2 (Ruppel): Flight paths for aerial surveys conducted for oblique photography on 22 and 23 October, 2009

The most noteworthy result of the aerial surveys conducted on 22 and 23 October was the lack of new seep sites identified on the coastal portion of the North Slope. A few new seeps were located east of the Meade River near Atqasuk. These results are probably not surprising given the different sediment characteristics (fine-grained from Barrow to Atqasuk and coarse grained near Prudhoe), ice content, permafrost thicknesses (thin on the west and thick on the east), distribution of pingoes (very prominent in Prudhoe area), nature of the underlying gas system (e.g., probably coalbed dominated near Atqasuk and conventional hydrocarbon dominated near Prudhoe), and lake history, morphology, and degree of thermokarsting in the different areas. However, one consideration is that numerous known seeps were not visible during our aerial flights on Oct. 22-23 not because they were frozen over; rather, because snow drift had likely temporarily filled them in. Conditions for surveying seeps was also hampered by poor visibility and fog. The aerial surveys were one approach to finding a seep location for the comparative fieldwork to be undertaken in Year 2. We have other leads and information to guide a decision about the exact field site for spring/summer of Year 2, and the group will be reviewing the options within the next 2 to 3 months.

Task 5.0 and 6.0 - Measuring methane flux on multiple temporal scales. Katey Walter Anthony (UAF): In late August, 2009 the UAF Walter Anthony laboratory group (Laurel McFadden with assistance from other technicians) worked on modifying and constructing methane flux traps for the purpose of continuous monitoring of methane seep dynamics. Our goal is to assess seasonal and long-term flux dynamics at seeps on a local interior Alaska thermokarst lake of biogenic origin and on seeps of geologic hydrocarbon origin on the North Slope of the Brooks Range, at Qualluraaq Lake. We have identified 17 seep locations on Goldstream Lake, a more typical thermokarst lake in interior Alaska than is Killarney Lake. The 17 seeps vary with regards to the magnitude of their daily fluxes, gas composition and isotope values, and distance from thermokarst shore, where permafrost is most actively thawing laterally. Two loggers were installed and maintained during the open water season. Trap construction continues, but as of Nov. 3, 2009, about half of the traps have been installed at Goldstream Lake and are collecting continuous flux data. Ice cover helps tremendously with installation of flux traps. During the last week of October, Katey Walter Anthony, Laurel McFadden, Peter Anthony, and Doug Whiteman conducted field work near Atqasuk, including installation of four-continuous flux traps over smaller geologic seeps on Lake Qualluraaq. The flux traps in Fairbanks will continue to operate throughout the year. Due to great ice thickness limitations and remoteness of location, traps will operate only until December at Lake Qualluraaq. We plan to retrieve the data and loggers from Lake Qualluraaq in December 2009.

Technicians in Walter Anthony's laboratory (Peter Anthony and Laurel McFadden) have worked with engineers at the UAF Alaska Center for Energy and Power and Doug Whiteman to design and construct a flow-meter for measuring and data-logging seepage from the large Lake Qualluraaq seep for several months. The flow measurement system is comprised of a weighted skirt, radiator, hose, pipe and flow meter; however, our attempt to deploy this flow measurement system during our October 2009 field campaign were delayed by a shipping backlog problem with Frontier Air Cargo Service. Finally, several hours after our departure from Atqasuk on Nov. 1, the 10' steel pipe was delivered to the site, completing the shipment of our equipment items. We will make a second attempt to install the flow measurement system in December, 2009.

We have collected replicate gas samples for geochemical analysis from the Lake Qualluraaq main seep during different times of the year, and all seep locations where flux is being measured. Geochemical data is still being generated on these samples (at UAF by Laura Oxtoby and Peter Anthony; at Florida State University by Dr. Jeff Chanton; and at UC Irvine and Woods Hole NOSAMS), but initial results suggest that methane from Killarney and Goldstream lakes is of modern biogenic origin, despite older ^{14}C ages of CH_4 due to a Late Pleistocene permafrost organic matter source that fuels methanogenesis. Methane from Lake Qualluraaq also appears to have a significant biogenic component, though significantly depleted ^{14}C ages of methane and the co-occurrence of coal particles at the seep sites suggest that it could be from a coal bed source. The geochemistry of the Lake Q gas is very similar to that of other biogenic origin gas well data collected down to depths of several hundred to several thousand feet below the ground surface at sites on Alaska's North Slope. Surprisingly, ^{14}C of Lake Qualluraaq and surrounding large seeps in nearby water bodies is not always ^{14}C-dead. This suggests that a modern methanogenesis based on decomposition of a relatively young organic matter source is also contributing to the seeps. Seasonal geochemical data from seeps collected from 2007-2009 as well as 13C-depleted values of a living chironomid at the Lake Qualluraaq seep site measured in 2007 suggests that (anaerobic) methane oxidation may also be playing a role seasonally in these methane seeps; however this question needs further exploration with integrated data from the project team.

Additionally, from October 20-Nov. 5, 2009 the Walter Anthony laboratory group conducted methane seep surveys using ground-based field work on 21 lakes: 10 interior Alaska lakes, including Goldstream L., Killarney L. and Smith L.; and 11 North Slope lakes, including Lake Qualluraaq, Coffee L. and Terrapin Station L. near Atqasuk and Barrow and Atqasuk, in order to assess how representative the intensive study lakes for this DOE project are on a regional basis. Data analysis is still underway; however, initial results seem to confirm the pattern that despite some variability between lakes, permafrost degradation is important for methane production and emission in interior Alaska lakes. While recent biogenic methane does not appear to be seeping in large quantities from North Slope lakes, geologic-based high-flux seeps are widespread in certain areas, undoubtedly a function of local geology, and perhaps also due to changes in permafrost thickness and distribution.

Finally, Katey Walter Anthony completed additional aerial surveys to add to previous data sets from 2007-2008 for the two study regions (Interior Alaska, North Slope of Brooks Range). The first 2009 survey during Oct. 22-23 was a joint USGS-UAF effort also described by Carolyn Ruppel. As noted, weather and lake ice cover conditions were not ideal during the Oct. 22-23 survey, so while a handful of potential seep sites were identified, their validity is questionable until further image and data analysis based on later (Oct. 28-Nov. 1) aerial and ground surveys and geochemical data have been analyzed. Our goal is to provide a comprehensive map of observed terrestrial geologic methane seeps for the North Slope of Alaska based on previously USGS-documented seep locations and additional recent observations by Katey Walter Anthony and others from 2007-2009. Our 2007-2009 aerial and ground-based surveys have confirmed the majority of previous USGS-documented seeps and identified >15 additional seep fields. The distribution and origin of seeps on Alaska's North Slope will be related to distributions of hydrocarbons, hydrocarbon geochemistry, regional geology, and permafrost. Implications for contribution of terrestrial geologic seeps in the Arctic to the global methane budget and climate change over millennial time scales will be assessed.

Task 7.0 - Methane oxidation in Alaskan thermokarst lakes. Monica Heintz (UCSB): All methane concentration, oxidation rate and stable isotopic samples from both May and July have been analyzed. May data has been fully processed and shared with project PIs. July data is currently being processed and inter comparison of results from the two sampling trips is in preparation. DNA was extracted from samples collected at the Lake Qualluraaq seep site and at LQ-CM site in both May and July. Preliminary Bacterial 16S rRNA clone libraries were constructed, and sequence analysis on 48 clones from each sample is in progress. Preliminary results indicate a strong seasonal effect on water column methane concentrations and oxidation rates.

Task 7.0 - Methane oxidation in Alaskan thermokarst lakes. Mary Beth Leigh (UAF) and Ruo He (UAF): Methane oxidation rates of water and sediment samples from Lake Qualluraaq and Killarney Lake were detected using microcosm incubations at 4°C, 10°C and room temperature. Methane concentrations in microcosms were monitored using gas chromatography during incubation. The highest methane oxidation rates were observed the sediment samples from LQ-West and LQ-CM, followed by the sediment samples from Killarney Lake, the least were those from LQ-seep. For water samples, the highest methane oxidation rates occurred in the samples from the bottom of Killarney Lake. Methanotroph medium was used to cultivate the microorganisms in water samples, and growth of methanotrophs was found in experimental water samples. For SIP, sediment samples were incubated with $^{13}CH_4$ in the laboratory under both aerobic and anaerobic conditions. The incubation is in progress and will be continued until a series of specific quantities of CH_4 are oxidized. When target oxidation extents are reached, the SIP samples will be harvested and frozen for later analysis of the identity and community structure of methane oxidizing microorganisms.

Task 7.0 - Methane oxidation in Alaskan thermokarst lakes and Task 8.0 - Establishing a long-term record of the variability in methane emissions in relation arctic climate change. John Pohlman's primary analytical effort for the samples collected in July has been focused on the volatile fatty acids (VFAs) and lipid biomarkers. These analyses were performed by Pohlman during an extended visit to the University of Bremen from 14 September to 19 October, 2009. Pohlman worked in and received technical support from the organic geochemistry group led by Dr. Prof. Kai-Uwe Hinrichs. During that time, 61 samples that include sediments and water column filters from the May and July field campaigns were extracted and prepared for intact polar lipid (IPL) analysis. All samples were fully processed and screened to identify the prevalent algal, bacterial and archaeal lipids. Splits from the extracts used from the IPL analysis were also Si column separated to investigate the isotopic composition of lipid components from the polar and apolar fractions. Last, approximately 120 pore water samples were analyzed by HPLC-IRMS to measure the concentration and isotopic content of the volatile fatty acids formate, acetate and propionate. Currently, samples from the core collected for paleoclimate reconstruction of the methane flux from Lake Qualluraaq are being processed by the AG Hinrichs organic geochemistry group. Analysis of the other pore water and gas components are also underway in Woods Hole MA.

Table 1 (Pohlman): July coring information

				Surface High-Res Core			*Long Core*		
Lake	Date	Core ID	Location	Core length (cm)	Sed Samples (qty)	Pore Water Samples (qty)	Core length (cm)	Sed Samples (qty)	Pore Water Samples (qty)
Qualluraaq	7/9/09	LQ-Seep-BGC	Seep Site	14	7	7	77	10	18
Qualluraaq	7/10/09	LQ-CM-BGC	Camp Monica	20	10	10	58	14	26
Qualluraaq	7/11/09	LQ-GPS22-BGC	Ground Ice Area	16	9	9	74	13	18
Qualluraaq	7/12/09	LQ-West-BGC	PaleoCoreSite	20	10	10	55	11	13
Killarney	7/16/09	KIL-NNE-BGC	NNE region of lake	16	8	8	83	17	20
Killarney	7/17/09	KIL-S-BGC	S side of lake	16	8	9	88	19	22
Killarney	7/17/09	KIL-NW-BGC	NW region of lake	18	8	9	75	15	18

Task 8.0 - Establishing a long-term record of the variability in methane emissions in relation arctic climate change. Matthew Wooller (UAF) and Ben Gaglioti (UAF) have primarily been involved in conducting measurements on the paleo cores (e.g. LQ-West, LQ-CM-Paleo, Terrapin Station and Coffee lake) collected from the May Field work. A total of 22 AMS radiocarbon samples have been prepared by Wooller and Gaglioti for submission to NOSAMS for dating. These included dates of the dark, 'coal' particles present in some of the cores, the results from which, as expected, were ^{14}C dead. In some areas of the cores from Qualluraaq Lake the 'coal' like particles were relatively dense (i.e. not mixed with sand) and formed distinct bands (Figure 3). These 'coal' layers also sometimes contained relatively soft, brown, wood fragments (examined under microscopy) that were also ^{14}C dead. The stable carbon isotope composition, %C content and morphology of the dark particles ('coal') in some of the cores are all consistent with them being coal ($\delta^{13}C$ = -25.3‰, %C = 57, $\delta^{15}N$ = 1.73‰, %N = 1.7). Stable isotope analyses (C and N) of total matter present in cores LQ-West and LQ-CM-Paleo have been prepared by Wooller and Gaglioti and analyzed at the Alaska Stable Isotope Facility, UAF. Stable carbon isotope analyses of chironomid fossils present in core LQ-West have been prepared by Wooller and Gaglioti and have also been analyzed at the Alaska Stable Isotope Facility, UAF. A basal age (from samples taken from the groups cores measured by NOSAMS) of core LQ-West shows that the organic portions overlaying the sandy substrate at the Lake Qualluraaq are ≤ ~12,000 calendar years old (calibrated using Calib 5.0). Preliminary results downcore indicate periods of time during the past when bulk carbon isotope data (Total Organic Carbon) match the data from the chironomids. However, some periods of time show the carbon isotopes of chironomids to be significantly lower than the data from the TOC, which in modern lake systems indicates ingestion of methane-derived carbon. Wooller and Gaglioti are preparing samples of chironomids for stable oxygen isotope analysis to reconstruct past climate change at the site over the ~12,000 years represented by core LQ-West. These data will ultimately be synthesized with the growing number of past climate change records emerging in the Arctic (many using fossil chironomid remains) (e.g. Kurek 2009). Magnetic susceptibility measurements and lithologic descriptions have been completed by Wooller and Gaglioti and archive cores from the May field work have been sent to Kelly Rose at NETL.

Figure 3 (Wooller): A cross section of LQSLC 509a core taken from the main seep in Qualluraaq Lake. Layers of dark particles at ~ 150-160 cm depth are shown amongst the overall lithology of grey sand.

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

One West Third Street, Suite 1400
Tulsa, OK 74103-3519

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South
Suite 201
Fairbanks, AK 99709

Visit the NETL website at:
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Customer Service:
1-800-553-7681