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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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QUARTERLY PROGRESS REPORT
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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 Alaska 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. Work during this quarter has focused on preparing presentations of the results related to all of the projects Tasks. The next quarter will also be dedicated to publishing the primary data from this project. Once the bulk of this primary data is published (efforts and scope described below) the group will focus on synthesizing the results from the separate tasks. This synthesis effort will subsequently address the final milestone related to the project to "Integrate laboratory results and complete a comprehensive analysis of methane seepage in thermokarst lake settings". With many of the papers documenting the primary data from the project nearing completion the group's efforts in the next quarter can be turned towards this final milestone. Analyses have focused on four main lake locations referred to in this report: Lake Qalluuraq (referred to as Lake Q) and Lake Teshekpuk (both on Alaska's North Slope) and Lake Killarney and Goldstream Bill Lake (both in Alaska's interior). Additional sites (Burial Lake and Quartz Lake) have been added by Wooller to supplement Task 8. Analyses of samples from Year 1 field work are virtually complete and data from this field work and sites are being included in a range of papers and presentations (see below). Analyses of samples collected from Year 2 field work at Lake Teshekpuk are being completed and will likely be complete during the next quarter.

Tasks 1 through 6: These tasks relate to field activities and have been completed and reported on in previous quarterly reports.

Task 7.0 - Methane oxidation in Alaskan thermokarst lakes. Mary Beth Leigh (UAF) and Ruo He (UAF): Stable isotope probing (SIP) microcosms have been conducted to identify and quantify active methane utilizing bacteria in sediments from a range of depths from several sampling sites from our study lakes. SIP sediment samples were harvested, a subsample was frozen immediately at -80ºC for molecular analysis and the remaining sediment was freeze-dried for phospholipid fatty acids (PLFA) analysis.

Five manuscripts reporting the results of microbial studies have been in preparation during this quarter, two of which have been submitted to ISME Journal and Environmental Microbiology. Submission of the remaining manuscripts is planned within the next quarter. PLFA-based SIP analyses have been completed and data analyses are in progress. Anaerobic methane oxidizers have been identified using DNA-SIP and microcosm incubations are being prepared to investigate anaerobic methane oxidation mechanisms. Dr. He's stay at UAF has been extended until Nov. to allow completion of the papers related to Task 7.0.

Task 8.0 - Establishing a long-term record of the variability in methane emissions in relation arctic climate change. Matthew Wooller (UAF) and Pohlman (USGS): The analyses of Lake Q are complete and a manuscript describing the results has been prepared and will be submitted on Aug 31st 2011 to a special issue of the Journal of Paleolmnology (JoPL). This paper includes biomarker data generated by German collaborators with Pohlman and our project. A follow up paper dedicated to the full suite of biomarker results is planned from Lake

Q. This JoPL special issue is dedicated to climate change records from arctic lakes. Decisions from the journal are expected within the next quarter. The technologies developed and applied to analyze the Lake Q west core have also been applied to two other long cores accessed by Wooller et al. (one from the Brooks range [Burial Lake] and covering the period ~25,000 years to present) and one from the discontinuous permafrost region in the interior of Alaska (Quartz Lake, ~12,000 year to present). A manuscript documenting results from Quartz Lake is complete and is also being submitted to the special issue of JoPL mentioned above. A full manuscript is complete from Burial Lake and is still being circulated amongst the co-authors for comments. Completion of the Burial Lake paper is expected within the next quarter. Gaglioti and Wooller continue to prepare samples from the year 2 field work conducted at Teshekpuk. Further AMS radiocarbon dates are being generated from the Teshekpuk field work . Samples from the Teshekpuk core have been sent to collaborators in Europe, who will be picking the remains of different taxa from the core during the next quarter. Wooller met with researchers from the University of Illinois who are interested to analyze charcoal from the Teshekpuk core to document past fire history in the surrounding vegetation and to compliment the paleoecological reconstruction of past climate change at the site.

Task: 9 - Geophysical analyses.

- Analysis of Lake Q geophysical data from Year 1 and full integration of SAR data into Heintz et al in prep manuscript is complete. SAR data analysis for grounded and non-grounded ice was completed by the USGS using data obtained under agreement with the UAF's Geophysical Institute for the period of Winter 2009 to 2010. .
- Analysis of Chirp seismic data and other data were undertaken at the USGS to produce a GIS-based gridded bathymetric map for Lake Q. Maps have been completed and are being included in some of the papers mentioned in this report.

Publications in the process of preparation and publication: (DOE project participants in bold):

G. Grosse, V. Romanovsky, T. Jorgenson, **K. Walter Anthony**, J. Brown, P. P, Overduin. 2011. Vulnerability and feedbacks of arctic permafrost to climate change. EOS Transactions, American Geophysical Union. In press.

Brosius, L.E., **K. M. Walter Anthony**, G. Grossee, J. Chanton, L. Farqharson, P. Overduin. (in review) Implications of δDCH4 from Alaskan thermokarst lakes for past and present atmospheric CH4 budgets. JGR Biogeoscience.

Ruo He, Matthew J. Wooller, John W. Pohlman, Catharine Catranis, John Quensen, James M. Tiedje, **Mary Beth Leigh**. (in review) Identification of functionally active aerobic methanotrophs in sediments from an arctic lake using stable isotope probing. Environmental Microbiology

Ruo He, Matthew J. Wooller, John W. Pohlman, John Quensen, James M. Tiedje, **Mary Beth Leigh**. (in review) Aerobic methanotrophs along depth profiles of arctic lake water column and sediments. The ISME Journal.

Ruo He, Matthew J. Wooller, John Pohlman, John Quensen, James M Tiedje, **Mary Beth Leigh**. (in review) Shifts in identity and activity of methanotrophs in arctic lake sediments in response to temperature changes. Environmental Microbiology.

Strohm, A., **K. M. Walter Anthony, F. Thalasso**. (in review) Seasonal methane emissions from an interior Alaska thermokarst lake. JGR Biogeoscience.

Matthew J. Wooller, et al. (in preparation) A ~12,000 year record of the variability in methane emissions from an arctic wetland related to climate change. Journal of Paleolimnology.

Matthew J. Wooller et al. (in preparation) A record of Late Quaternary climate change in the northwestern Brooks Range, Alaska derived from stable isotopic analyses of chironomids. Quaternary Research.

Matthew J. Wooller et al. (in preparation) 11,000 years of climate and limnological change from Quartz Lake, Alaska. Journal of Paleolimnology.

Presentations:

An AGU abstract was submitted by DOE NETL, USGS and UAF collaborators on this project.

Lithology of Alaskan Thermokarst Lake Facilitates Methane Flux

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Thermokarst lakes of the Alaska North Slope (ANS) are a prevalent landform that emits significant quantities of the greenhouse gas methane to the atmosphere. These lakes form in permafrost regions and result in the development of a thaw-bulb (talik) beneath the lakes. When a talik intersects faults linked to natural gas accumulations, coal beds or permafrost-associated gas hydrate, methane can be released from the lake. In 2009, a four-core transect extending from an active seep in Qalluuraq Lake (Lake Q), an Alaskan thermokarst lake, was taken for lithological analysis to complement paleoecological and biogeochemical studies investigating the current and historical flux of methane from this lake. As part of this study, we completed sedimentalogical analyses to constrain the lithology of the system and evaluate potential near-lake floor geologic controls on methane seepage at this site. Visual descriptions were completed for each core. Grain size, x-ray diffraction, petrographic, elemental (C and N) and accelerator mass spectrometer (AMS) radiocarbon analyses were also conducted on subsamples from the cores. The major lithology of all four cores is a quartz-rich, chert-bearing, medium-grained sand. Organic material, including grasses, seed pods, and reworked coal fragments, was observed in some intervals as laminae or as dispersed material. Some of the AMS dates on organic laminae in the cores fit with paleoecological reconstructions from the site relating to wetland succession, although XRD and petrographic analyses indicate quartz is the dominant mineral in every core. Feldspar, clays, and micaceous minerals are also present throughout the cores in trace to minor amounts. Though the Lake Q is presently a lacustrine environment, likely formed via thermokarst processes, its underlying sediment is fluvially reworked marine sands. These sediments belong to the Gubik Formation, a Quaternary age sedimentary formation that blankets much of the ANS, encompassing a range of depositional environments, including nearshore marine, fluvial, lacustrine, eolian, thermokarst and glacial. Methane ebullition resulting from

wetlands initiation ~12,000 cal yr BP has apparently winnowed fine-grained organic material from the active seep sediments. The resulting coarse-grained and moderately well-sorted seep sediments are an unrestricted conduit that facilitates the gas and fluid flux to the lake and atmosphere.

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