PS Focusing Petroleum Exploration with Regional Geochemical Surveys*

David M. Seneshen[1] and John V. Fontana[1]

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[1]Vista Geoscience, Golden, CO, USA (DSeneshen@VistaGeoScience.com, JFontana@VistaGeoScience.com)

Abstract

A regional onshore geochemical exploration survey was carried out over the Yukon Flats and Nenana basins in east-central Alaska. The objectives of the survey were to focus exploration within a 2,100 square mile area and demonstrate the existence of liquid hydrocarbons in these supposed "gas-prone" basins. Lake bottom sediments were chosen as the preferred sample medium for the survey because the lakes are thought to be thermal windows through permafrost, they can be collected rapidly with helicopter support, and their effectiveness for detecting oil and gas fields was demonstrated in a previous study over the Tuk oil and gas fields in the Mackenzie Delta of northern Canada. The lake sediment samples were analyzed for headspace, saturated and unsaturated C1 to C7 hydrocarbons and for traces of crude oil using Synchronous Scanned Fluorescence. The regional lake sediment geochemical survey over parts of the Yukon Flats and Nenana basins was effective in that liquid hydrocarbons were detected and the initial 2,100 square mile survey area was reduced to about 500 square miles of prospective ground based on the location of oil and wet gas microseeps. The location of a subsequent 40 square mile 3D seismic survey was guided by the results of the geochemical survey. Regional lake sediment geochemical exploration surveys are a cost-effective tool for demonstrating the existence of liquid-based petroleum systems in remote untested basins. The surveys also help focus more cost-prohibitive geophysical surveys and drilling.

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David M. Seneshen[1] and John V. Fontana[1]

[1]Vista Geoscience, 130 Capital Drive, Suite C, Golden, Colorado, USA; PH: 303-277-1694
DSeneshen@VistaGeoScience.com JFontana@VistaGeoScience.com,

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We are grateful to Doyon Limited for allowing us to present these results and for providing basement maps to superimpose the geochemical data on.

Regional, low density (0.67 samples per mile^2), lake sediment geochemical exploration surveys were carried out over the Yukon Flats and Nenana Basins in northeast Alaska. The objectives of the survey were to focus exploration work (e.g. seismic) within a 2,100 mile^2 area and demonstrate the existence of migrated liquid hydrocarbons in these previously labeled "gas-prone" basins. Lake bottom sediments were chosen as the preferred sample media for the survey because the lakes are thought to be thermal windows through impermeable permafrost (Burn, 2005), they can be collected rapidly and cost-effectively with helicopter support, and the effectiveness of this sample medium for detecting oil & gas fields was demonstrated in the Mackenzie Delta of northern Canada (Seneshen and Fontana, 2010). The lake sediment samples were analyzed for headspace, saturated and unsaturated C_1 to C_7 hydrocarbons and also for traces of crude oil using Synchronous Scanned Fluorescence.

The regional lake sediment geochemical survey over parts of the Yukon Flats and Nenana basins was effective in that liquid hydrocarbons were detected and the exploration potential of the initial 2,100 mile^2 survey area was reduced to about 480 mile^2 (~76%) based on the location of oil and wet gas microseeps. The location of a subsequent 52 mile^2 3D seismic survey at Stevens Village was guided by the results of this geochemical survey. Regional, low density, lake sediment geochemical surveys are a cost-effective tool for demonstrating the existence of petroleum systems in remote, untested basins, and also for focusing more cost-prohibitive geophysical surveys and drilling. Future work in the 480 mile^2 geochemically anomalous areas should include more detailed geochemical surveys using soil cores as a sample medium to better define the shape and size of microseepage anomalies, and 2D seismic surveys to look for potential traps for migrated oil and gas.

References

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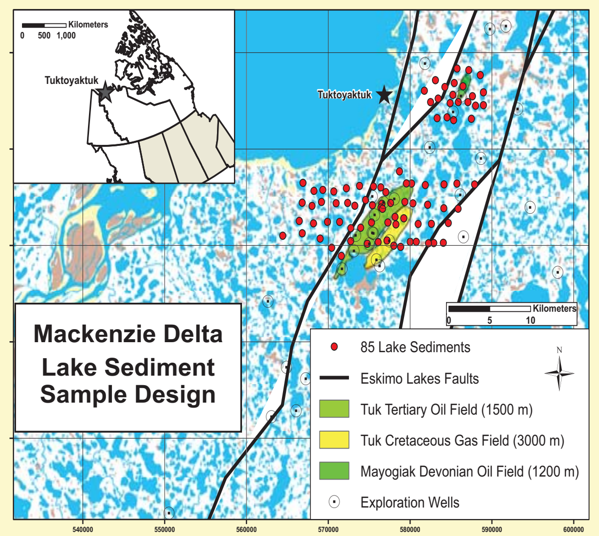
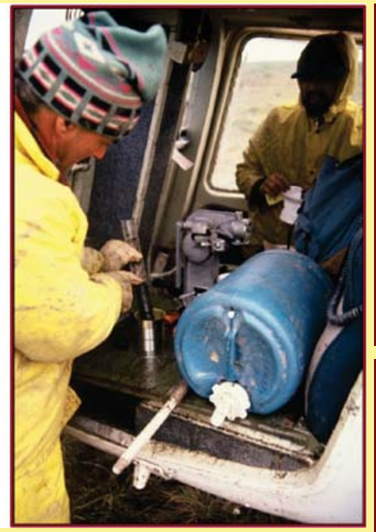
Pixler, B.O., 1969. Formation evaluation by analysis of hydrocarbon ratios. Journal Petroleum Technology, Vol. 21, pp. 665-670.

Seneshen, D.M. and Fontana, J.V., 2010. Unique Geochemical Methods for Regional On-shore Petroleum Exploration in the Mackenzie Delta, Northwest Territories, Canada. Search and Discovery Article #90108. American Association of Petroleum Geologists International Convention and Exhibition, Calgary, AB, September 12-15, 2010.

Lake Bottom Sediment Collection (Mackenzie Delta, NWT, Canada)

Lake bottom sediments were collected over the Tuk Tertiary oil field (1500 m depth), Tuk Cretaceous gas condensate field (3000 m depth), and the 1,200 meter deep Devonian Mayogiak oil fields in the vicinity of the town of Tuktoyaktuk, NWT Canada. A total of 85 lake bottom sediments were collected at 1 to 2 km intervals over approximately 63 miles^2 (1.35 samples per mile^2). Organic-rich lake sediment was collected from depths of 0.3 to 0.6 m below the lake floor with a 30 kg (65 lb) gravity core dropped from a helicopter equipped with pontoons. A 250 cc volume of the lake bottom sediments was placed in a 500 ml can immediately upon removal from the core barrel. The remaining volume was filled with hydrocarbon-free distilled water and bactericide to prevent microbial degradation of the light C_1-C_7 hydrocarbons. The can was then sealed on-site with a canning machine, and a 100 ml volume of fluid was displaced with pure nitrogen injected through a septa in the lid.

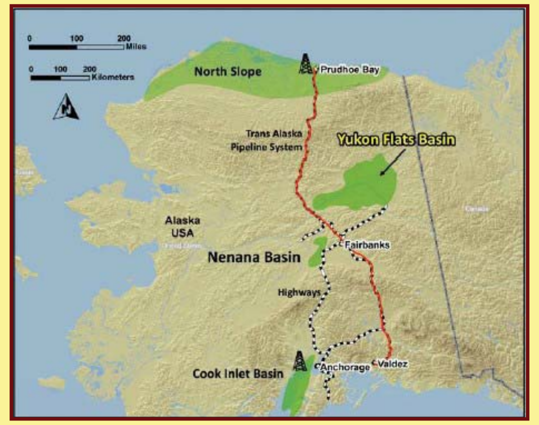




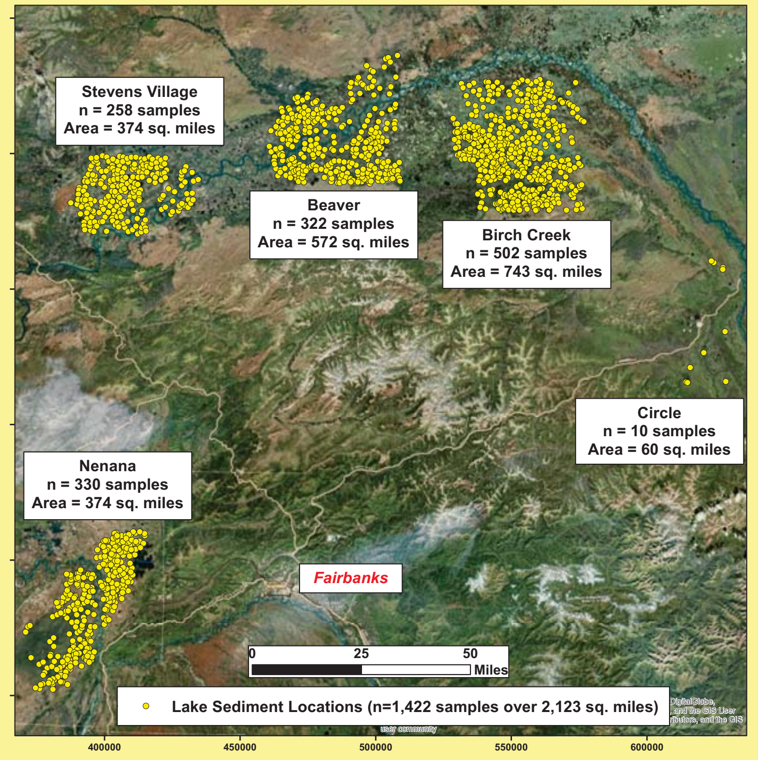
The Pleistocene glaciated terrain over the Mackenzie Delta is generally flat with a uniform distribution of periglacial lakes. Lake bottom sediments were chosen as a preferred sample medium for the study because of the uniform distribution of abundant lakes in this region. The Pingo (Eskimo name for "small hill") shown in the photograph was formed by permafrost rise into a drained lake or river channel. Pore water is expelled in front of the rising permafrost, and the resulting pressure causes the frozen ground to rise and an ice core to form.

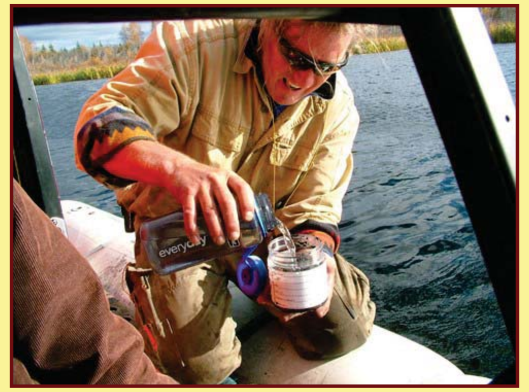
Lake Bottom Sediment Collection (Yukon Flats and Nenana Basins, Alaska)

A total of 1,422 lake bottom sediments were collected at 1 to 2 mile intervals over approximately 2,100 miles^2 (0.67 samples per mile^2). Organic-rich lake bottom sediment was collected from depths of 0.5 to 3 m below the lake floor with an "Aquatic Research" piston corer while standing on the float of a helicopter. Isojars (with septa in the lids) were filled with 50% lake sediment and 50% deionized water with bactericide to prevent hydrocarbon degradation.



The Yukon Flats and Nenana ecoregion is a relatively flat, marshy basin which has braided, meandering rivers and streams, and numerous thaw, basin, and oxbow lakes. In general, the lakes are much shallower (<20 feet) than in the Mackenzie Delta.



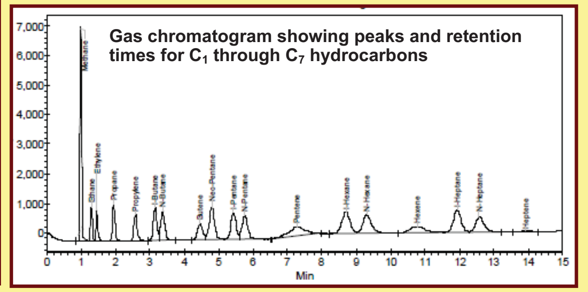


Hydrocarbon Analysis of Lake Bottom Sediments and Interpretation

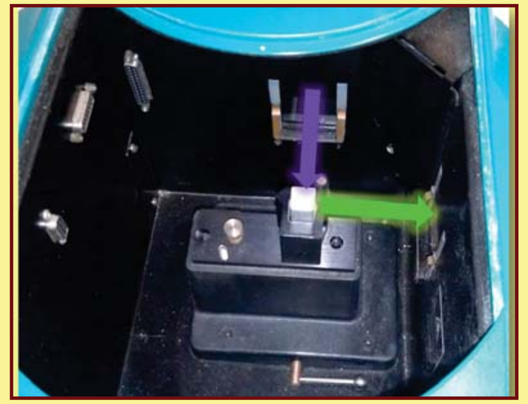
Hydrocarbons were liberated from the lake sediments the headspace of the cans and Isojars by heating (80 °C) and agitation. An aliquot of gas was then withdrawn into a syringe from the can and injected into an gas chromatograph with a flame ionization detector for the analysis of methane (C_1), ethane (C_2) ethylene (C_2), propylene (C_3), iso– and normal butane (C_4), iso– and normal-pentane (C_5), iso– and normal-hexane (C_6) and iso– and normal heptane (C_7) by Flame-Ionization Gas Chromatography (FID/GC). Dried and sieved (<63 microns) splits of the lake sediments were also analyzed by Synchronous Scanned Fluorescence for C_6-C_{36} aromatic hydrocarbons (indirect measure of crude oil microseeps).

The hydrocarbon data were compiled and log-transformed in Excel and statistically evaluated using Statistica 7.0. The thresholds between background and anomalous hydrocarbon concentrations were picked off histograms and discriminant analysis was used on the Tuk and Mayogiak headspace hydrocarbon data to evaluate how well the method could distinguish between anomalous and background conditions over and off the oil & gas fields. Hydrocarbon concentrations were plotted as proportional symbols on topographical or structural backgrounds in ArcGIS 10.0 and canonical score plots from discriminant analysis were prepared in Statistica 7.0.

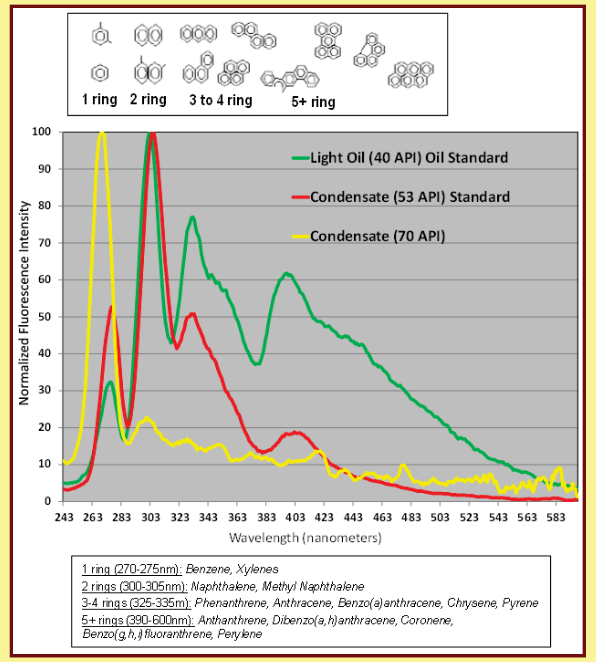
Flame-Ionization Detection Gas Chromatography (FID-GC)



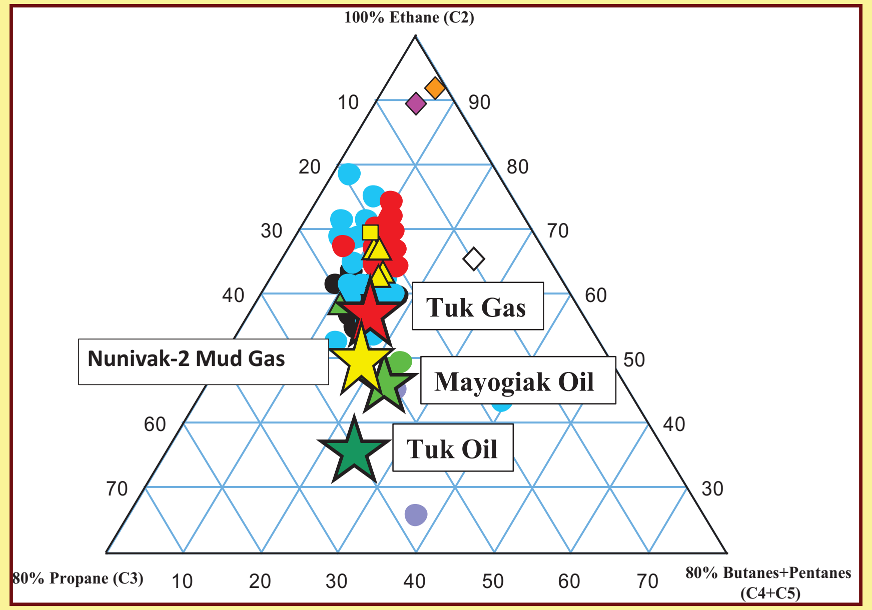
Synchronous Scanned Fluorescence

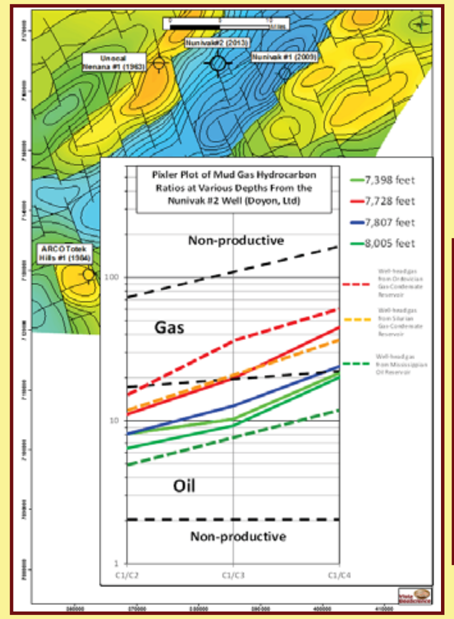


UV-Vis Fluorescence Spectrophotometer

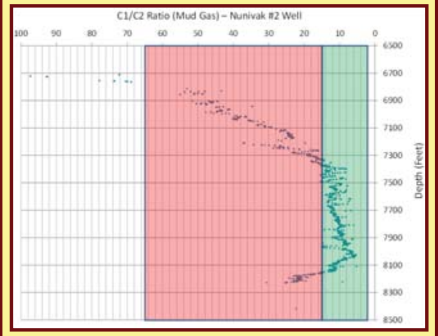


Composition of Reservoir Fluids (Mackenzie Delta and Nenana Basin)





Pixler plot (Pixler, 1969) of mud gas from various depths the Nunivak#2 well that was drilled in 2013. The formation gas was derived from a light oil and/or condensate source. Below is a plot of the C1/C2 ratio in mud gas from 6,500 to 8,500 foot depth. The formation gas from 7,400 to 8,150 foot depth were derived from a light oil source.



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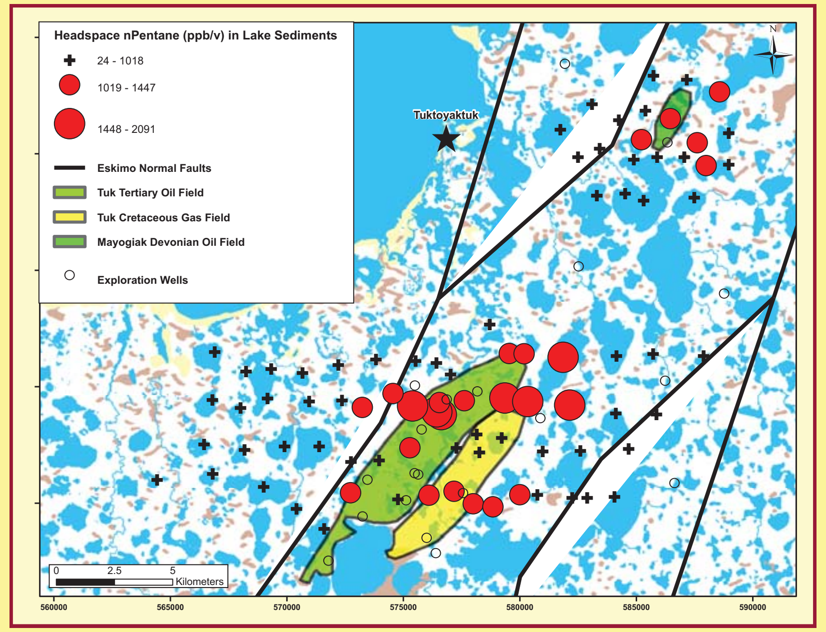
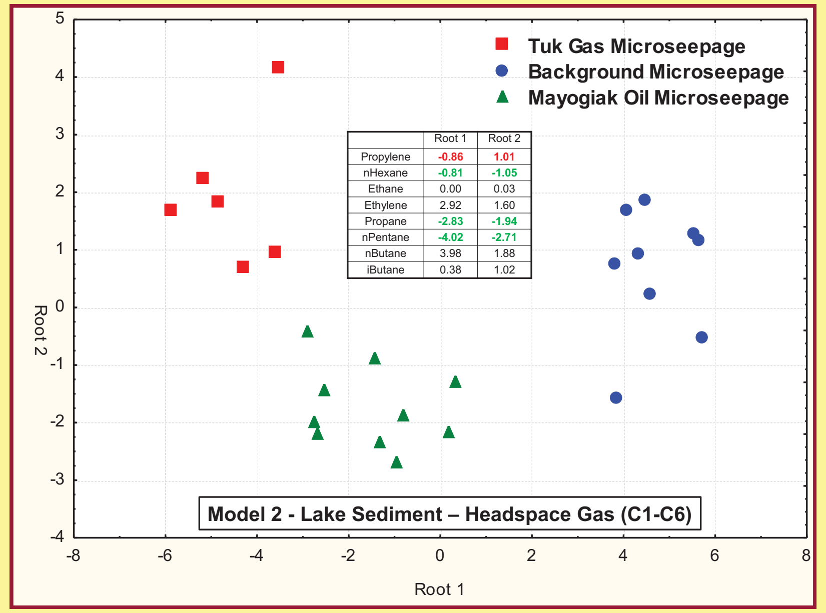
Mackenzie Delta Lake Bottom Sediment Geochemical Results

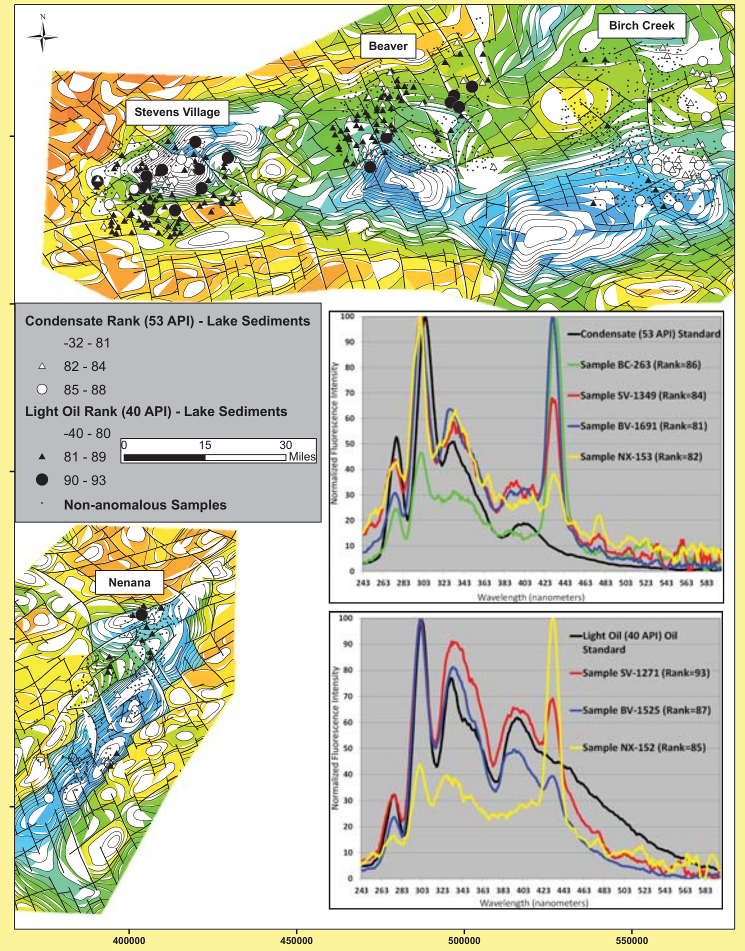


Distribution of headspace nPentane (C5) in lake sediment samples over and around the Tuk and Mayogiak oil and gas fields. There is good spatial correlation of the nPentane anomalies with the Tuk and Mayogiak oil & gas fields. Anomaly contrast is about 2.

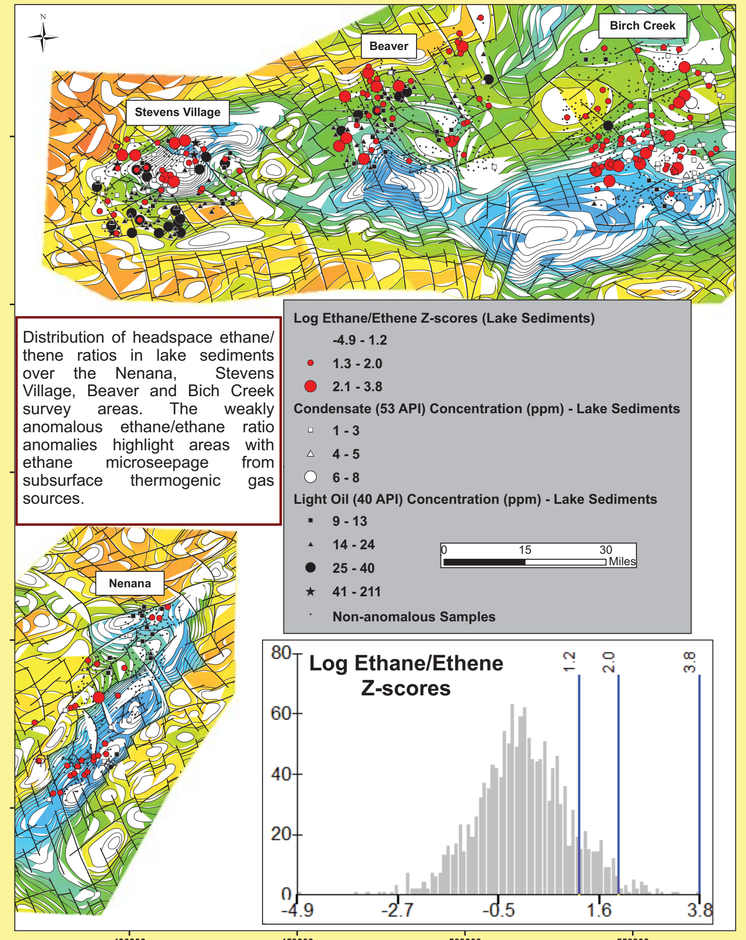


Canonical score plot from discriminant analysis of the lake sediment headspace hydrocarbon data using samples over the Tuk gas field, Mayogiak oil field and background areas as a training set. Microseepage over the Tuk gas field, Mayogiak oil field and background areas are compositionally distinct based on discriminant analysis of the C_1-C_6 hydrocarbon data. Propylene is the most important variable for differentiating microseepage over the Tuk gas field from that over background areas and the Mayogiak oil field. Variables that contribute most to the discrimination of microseepage over the Mayogiak oil field from background areas and the Tuk gas field are nPentane, propane and nHexane.

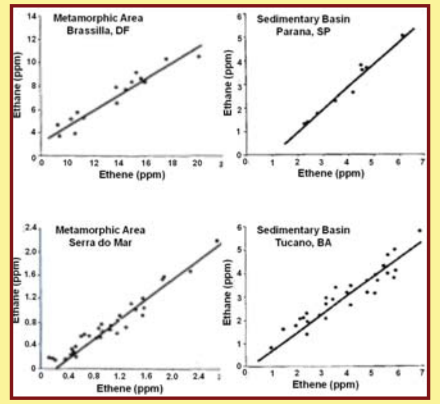
Yukon Flats and Nenana Basins Lake Bottom Sediment Geochemical Results

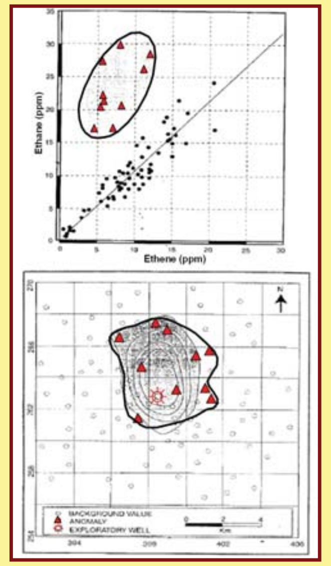


Distribution of condensate and light oil microseeps based on the similarity (rank out of 100) between normalized fluorescence spectra of condensate and oil standards with the microseeps in the lake sediment samples. The light oil microseeps are most abundant in lake sediments over Beaver and Stevens Village areas and condensate-like microseeps predominate over the

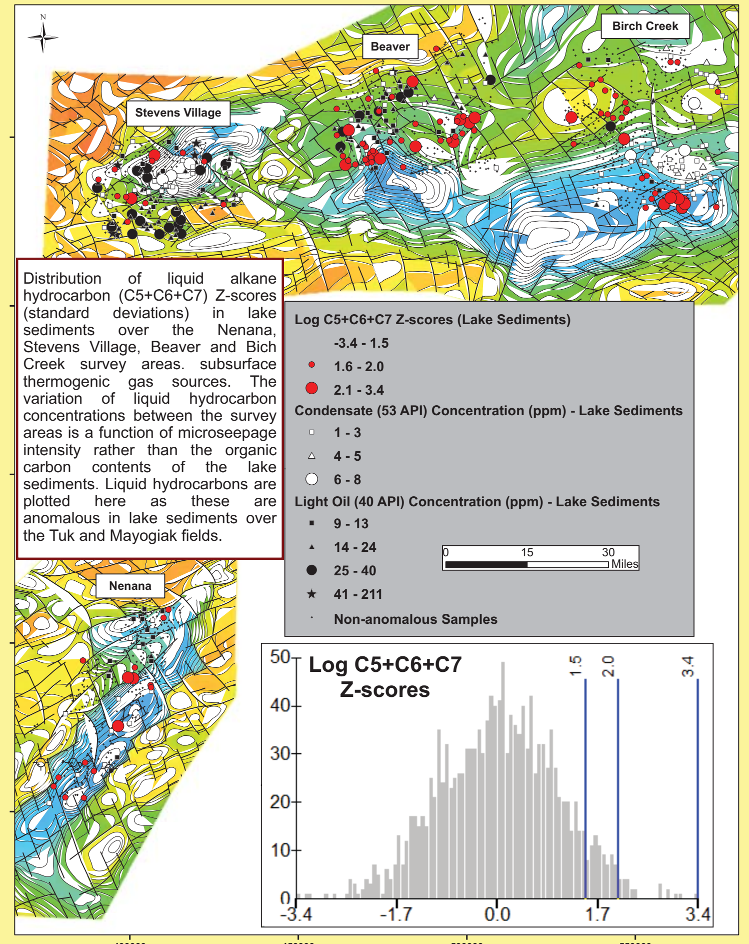


Distribution of headspace ethane/thene ratios in lake sediments over the Nenana, Stevens Village, Beaver and Bich Creek survey areas. The weakly anomalous ethane/ethane ratio anomalies highlight areas with ethane microseepage from subsurface thermogenic gas sources.

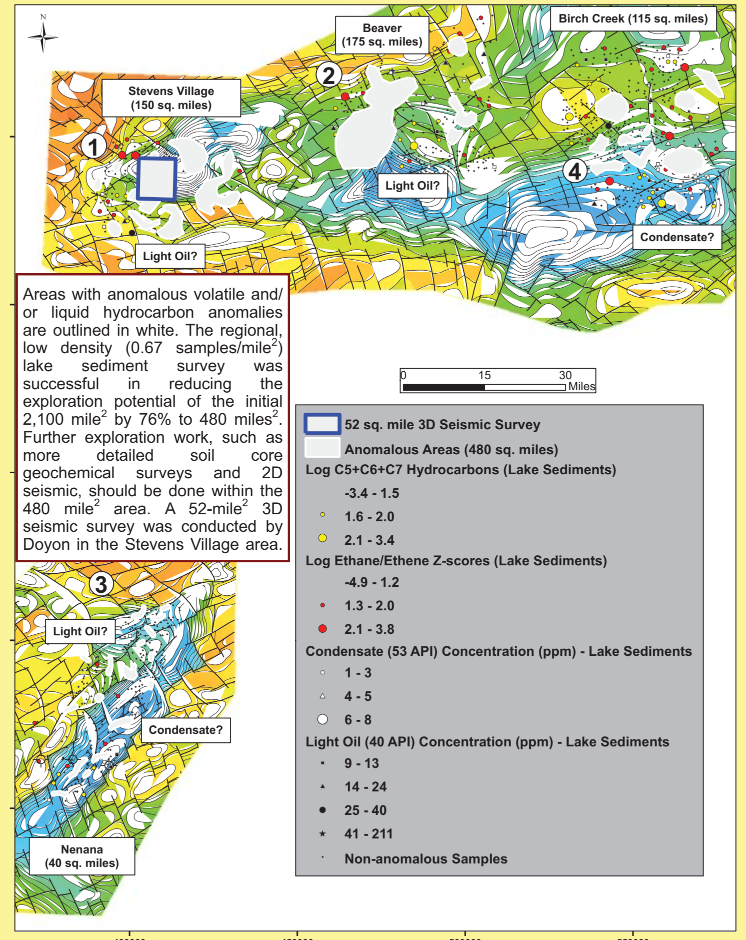




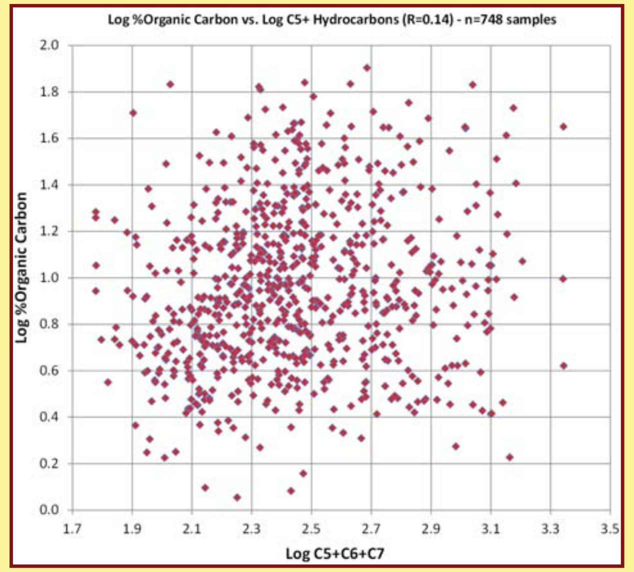
Ferreira (2002) showed that light, saturated and unsaturated hydrocarbons have been detected in soil gas surveys over both sedimentary basins and also crystalline basement with no source rocks meaning that light hydrocarbons must be produced by near-surface biochemical processes. Added saturated hydrocarbon microseepage from subsurface thermogenic sources increases the saturated/unsaturated ratio, which gives a true representation of microseepage from oil & gas sources. Ferreira (2002) demonstrated this relationship by a spatial plot of ethane residuals in the ethane/ethane cross-plot. The ethane residuals all plot over an area in Brazil where a large gas field was discovered.



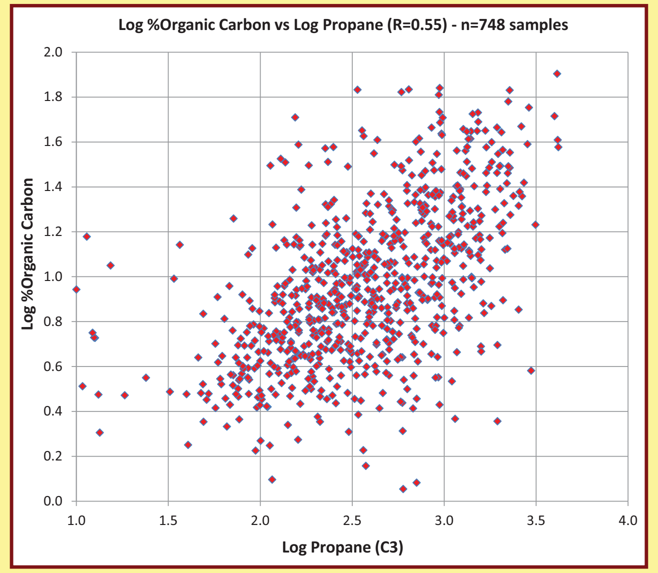
Distribution of liquid alkane hydrocarbon (C5+C6+C7) Z-scores (standard deviations) in lake sediments over the Nenana, Stevens Village, Beaver and Bich Creek survey areas. subsurface thermogenic gas sources. The variation of liquid hydrocarbon concentrations between the survey areas is a function of microseepage intensity rather than the organic carbon contents of the lake sediments. Liquid hydrocarbons are plotted here as these are anomalous in lake sediments over the Tuk and Mayogiak fields.



Areas with anomalous volatile and/or liquid hydrocarbon anomalies are outlined in white. The regional, low density (0.67 samples/mile^2) lake sediment survey was successful in reducing the exploration potential of the initial 2,100 mile^2 by 76% to 480 miles^2. Further exploration work, such as more detailed soil core geochemical surveys and 2D seismic, should be done within the 480 mile^2 area. A 52-mile^2 3D seismic survey was conducted by Doyon in the Stevens Village area.



The low correlation (r=0.14) between organic carbon content of the lake sediments and headspace liquid alkanes (C5+C6+C7) proves that the variation in log C5+ hydrocarbons shown above is not simply related to variable organic carbon content in the lake sediments. This is important to document as it is intuitive that more organic matter in the lake sediments would lead to more light hydrocarbon adsorption. In fact this is true for the volatile hydrocarbons (e.g. propane) as shown by the significant correlation (r=0.55) of organic carbon content and propane concentrations in the lake



Conclusions

The objectives of this study were to conduct a regional geochemical survey in the Yukon Flats and Nenana Basins to (1) prove or disprove the existence of migrated liquid hydrocarbons in the basins, and (2) focus more expensive exploration work (e.g. seismic) in this very large 2,100 mile^2 area. The objectives of the study have been met based on the following points:

- The presence of crude oil and condensate microseeps demonstrates oil generation and migration within both the Yukon Flats and Nenana Basins.
- The clustering of volatile and liquid hydrocarbon microseeps in the basins has helped focus the search for oil to a 480 mile^2 area from an initial 2,100 mile^2 area.
- Lake bottom sediments are an effective sample medium for regional, low density, geochemical exploration for petroleum based on the positive results from the Mackenzie Delta and the Yukon Flats and Nenana Basin survey. Fluorescence and headspace hydrocarbon analyses of the lake sediments are effective methods for the identification of volatile and liquid hydrocarbon anomalies on a regional basis.
- The 480 mile^2 area of hydrocarbon microseepage should be followed up with more detailed soil core based geochemical surveys and 2D seismic anomalies. A 52 mile^2 3D seismic survey was carried out at Stevens village in 2013 with very favorable results based on the outcome of this geochemical survey.