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**Development of the Tarn Field Geochemistry Analog and Subsequent  
North Slope Basin Reconnaissance  
Permafrost Cores and Gas-Sieve Methods**

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**Geology at Tarn**

The Tarn Field located in T9N, T10N-R7E North Slope, Alaska is a turbidite oil field that was discovered by ARCO/Phillips Alaska in the mid-1990's and has on-going development. Tarn produces 40-API gravity oil from the stratigraphically trapped Lower Cretaceous Torok Formation at a depth of about 5,000-6,000 feet BGL. Recoveries from the field are expected to exceed 70 MMBO. The Torok Formation sands occurring west of Tarn to the Collville River are older and deeper in the section however; they do have the same source and depositional environment as at Tarn.

Above the Torok Formation lies Upper Cretaceous and Paleocene sand (Cirque/Tabasco) that embody gas hydrates from about 1000 feet BGL to 2400 feet BGL. Just under these hydrates there can exist free gas that has migrated from deeper horizons and whose migration is temporarily slowed by the physical presence of the hydrates that creates a temporary trap. An indication of the large volumes of gas trapped under the hydrates was evidenced by a 10 MMCFD blowout at the Cirque #1 well near Tarn. Down dip, over part of the Lease Sale area and under the hydrate stability zone, the free gas may begin to change to an oil leg.

**Geology at the Lease Sale Project**

The Lease Sale Project is located between T7N, T8N and R4E-R6E on the North Slope. The Lease Sale area is about 5 miles south and 5-8 miles west of the Tarn Project. Here, between the deeper Torok Formation and the Cirque sand lies deltaic sands of the Nanushuk Formation. The Nanushuk wedges northward into this area from a large fluvial system sourced by the Brooks Range. These delta sands are absent at Tarn but are potentially productive in the Lease Sale area at 4000 feet BGL. The delta sands image strongly on seismic when they are developed.

**Hypothesis**

Tarn was chosen as the an area to test the hypothesis that thermogenic hydrocarbons migrate from reservoirs below, to and through established hydrates trapped in a permafrost zone and into the near surface with eventual discharge to the atmosphere. Tarn was chosen because the field is young, permanent roads exist and many believe that more Tarn like fields will be discovered west of Tarn.

**Project goals**

The operator's goals for the Tarn geochemistry survey were to develop permafrost coring tools and techniques and to demonstrate that there were extensive thermogenic hydrocarbons in the shallow permafrost cores over the field. Once these goals were met, the information gained

would then be applied to near-by open acreage available in the November 2000 Area-wide sale. Of secondary importance was the development of an extensive geochemistry model defining Tarn.

The operator designed the Tarn survey without fully knowing Phillips Alaska's future drilling plans and without the areal extent of the field defined as we know it today. Periodically drilling results and production figures have been released to the public and now the field is larger than previously thought. The result of these planning limitations was an irregular sampling plan and very little background geochemistry data having been collected. An interesting, if not complete geochemistry analog of Tarn was the result.

### **Permafrost coring methods and processing**

To test the migration hypothesis and develop a geochemistry analog for the Tarn Field, twenty-nine 2" X 30" frozen sediment cores were taken from 0-30" BGL over the Tarn Field in the winter of Y2000. The soil cores were collected in their core barrels and shipped frozen via Fed Ex to the lab. At the lab the cores were mechanically extruded and 500 grams were removed from the interval below the active layer, the section was weighed and measured and placed in a gas tight chamber. Nitrogen purged water was then metered into the vessel. The contents were sonically disrupted and a volume of the headspace gas was metered from the vessel across a gas-sieve.

### **Gas-sieve function and analysis**

A gas-sieve is a clear glass device similar in size and shape to a soda straw that is filled with sieving material (Figure 1). The gas-sieve acts as a hydrocarbon collection and concentration device that is used to address problems with trace gas analysis. When soil vapor is drawn across the gas-sieve the hydrocarbons present are trapped on the sieving material until thermally released into a GC or GC/MS. The light hydrocarbons C1-C6 and longer chain hydrocarbons (up to C20) are trapped.

For this project, gas-sieve samples from the frozen sediment cores were analyzed in a GC using TDU Method FID-98 and PID/FID detectors run in series. The analytes were methane, ethane, propane, isobutane, n-butane, pentane and hexane. The longer hydrocarbons (up to C20) were not project analytes but their presence could have been used for MS pattern matching of hydrocarbon signatures or families.

Where prior art geochemistry, "direct inject syringe methods", would allow no more than 2-5 ml of headspace gas from the frozen cores to be analyzed, gas-sieve methods allow the analyst to introduce significantly more analyte (hydrocarbon from 1 or more liters of vapor) onto the GC column. The result is that the analyst can work well above the detection limits and analytical noise of the GC negating many of the analytical problems inherent in trace gas analysis.

### **Light hydrocarbon gas-sieve data from Tarn**

Two types of data are gleaned from the gas-sieve analysis: the concentration of the hydrocarbons in each sample and the composition of the hydrocarbons. As a generalization, concentration data provides information about the size and shape of the hydrocarbon-bearing portion of the reservoir. The compositional data gives indications of the nature of the reservoir fluid i.e. low or high gravity oil, wet or lean gas, gas cap location, compartmentalization of oil or gas and existence of various hydrocarbon families by pattern matching.

Map 1 data suggests the areal extent of the Tarn Field and some better hydrocarbon bearing areas within the field. Map 2 (ratios C2/C4) depicts areas of Tarn exhibiting similar composition. C2/C4 ratios ranging from 2.4 to 5.0 suggest that the Tarn reservoir is producing

high gravity oil with some associated gas. Analysis of the well head gas produced at Tarn reveals that C<sub>2</sub>/C<sub>4</sub> ratios are indeed 5.2-5.5. Further, areas of the Tarn Field exhibiting C<sub>2</sub>/C<sub>4</sub> ratios near 5 are where the most highly productive wells in the field are producing 4,000-8,300 BOD each.

Studies conducted elsewhere over reservoirs producing 22-API gravity oil have shown that C<sub>2</sub>/C<sub>4</sub> ratios in a range of 0.5 – 1.9 are indicative of lower gravity oil. The 0.5 end of the range having little associated gas and the 1.9 end of the range having higher volumes of associated gas.

### **Lease Sale Project – survey design and methods modification**

With the successful completion of the Tarn Field phase of the project, the crew was remobilized to the field to acquire permafrost soil cores on open acreage. A sample density of one (1) core in the center of each section was chosen because it was determined that this sample density would have discovered Tarn even though it would not have defined the field well. The sampling pattern was more grid like than at Tarn and the goal was basin reconnaissance. One hundred-nineteen (119) - 2" x 30" cores were taken in T7N, T8N-R4-6E on the North Slope in the Lease Sale area. Differences in sample handling from the Tarn Field were related to extrusion and vacuum packing of the cores while still on the North Slope to reduce shipping costs. All other procedures were the same for both areas.

### **Light hydrocarbon gas-sieve data from the Lease Sale project**

Map 3 (Total Hydrocarbons) suggests that there are several geochemistry anomalies on the Lease Sale area similar in size to the Tarn Field. The anomalies are strong relative to background levels with at least 50% of the sample locations defined as "background" and having total hydrocarbons (C<sub>2</sub>, C<sub>3</sub>, iC<sub>4</sub>, and C<sub>4</sub>) less than 75,000 ng/Kg of soil. Map 4 (C<sub>2</sub>/C<sub>4</sub> ratios) suggests that there are very subtle differences between the composition of the migrating gases between Tarn and the Lease Sale. These differences may be insignificant once sample density between the two projects is given consideration.

### **Pixler plots and hydrocarbon families at Tarn and the Lease Sale**

Figure 2 depicts the four hydrocarbon families at the Lease Sale. Note that Family 1 and 3 are very similar and they may be one family. Family 1 and 3 are interpreted, by comparison to Tarn, as high gravity oil bearing areas. Family 2 and 4 members represent background with high methane and without high methane. Those with high methane are geologically explained as areas of near surface Cirque hydrate subcrop.

### **Conclusions**

Without doubt there are thermogenic light hydrocarbons in elevated concentration above the Tarn Field. In the Lease Sale area, hydrocarbon concentration and compositional data suggest that the elevated geochemical anomalies are similar to Tarn. Background values, though not established at Tarn, become evident at the Lease Sale area.

Additionally, the compositional data at the Lease Sale suggests that oil encountered in the prospective pay should be high gravity similar to the oil at Tarn. The project operator suggests that there are Torok and Nanusuk 2-D seismic anomalies that correspond to the geochemistry anomalies at the Lease Sale area. The seismic lines were not released for inclusion here.

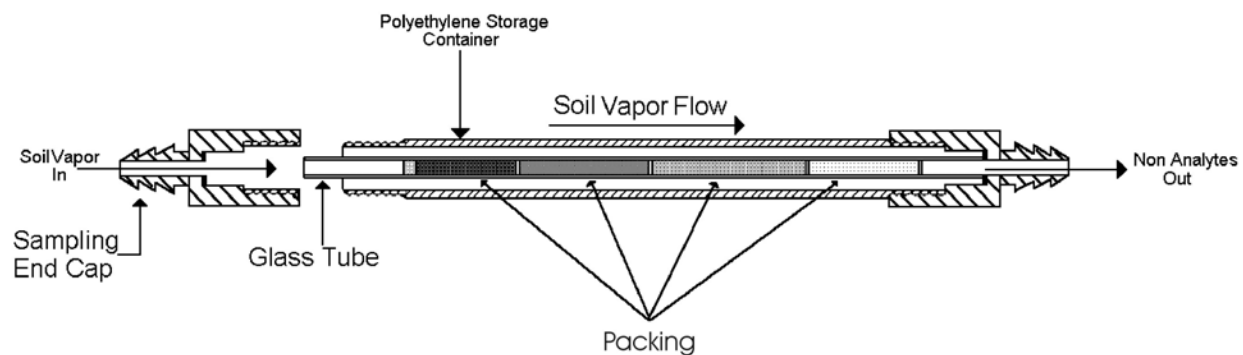


Figure 1: Gas-Sieve

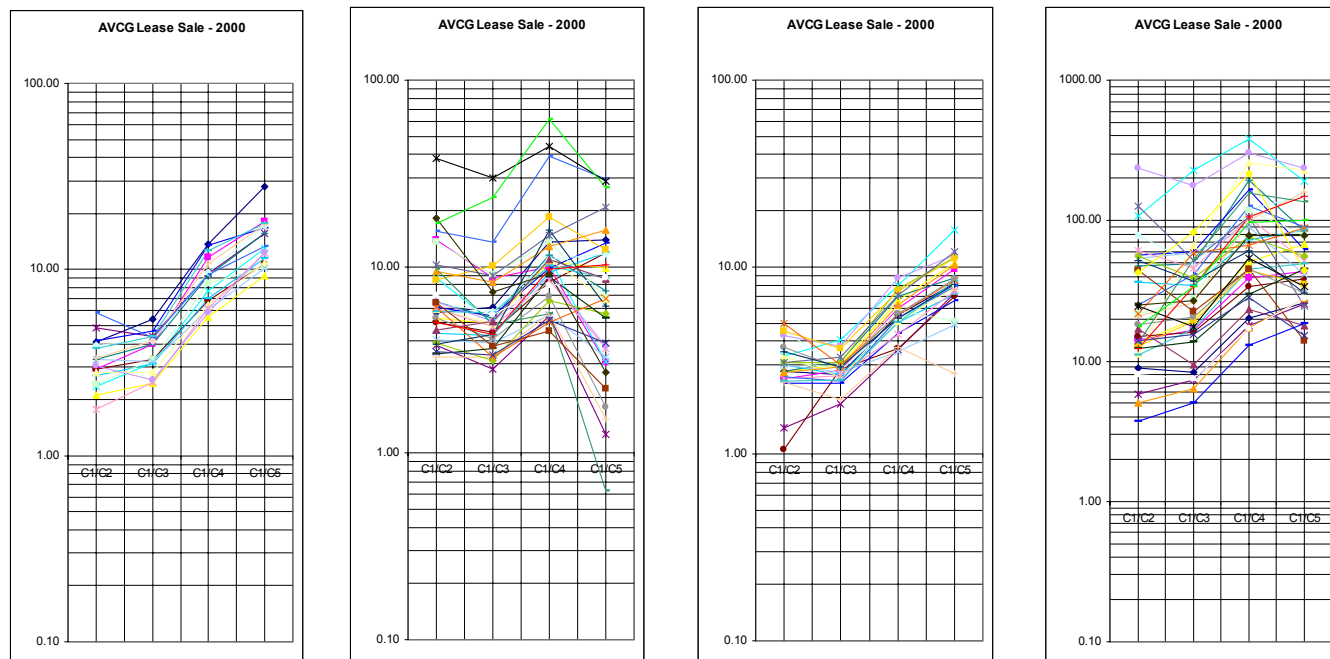
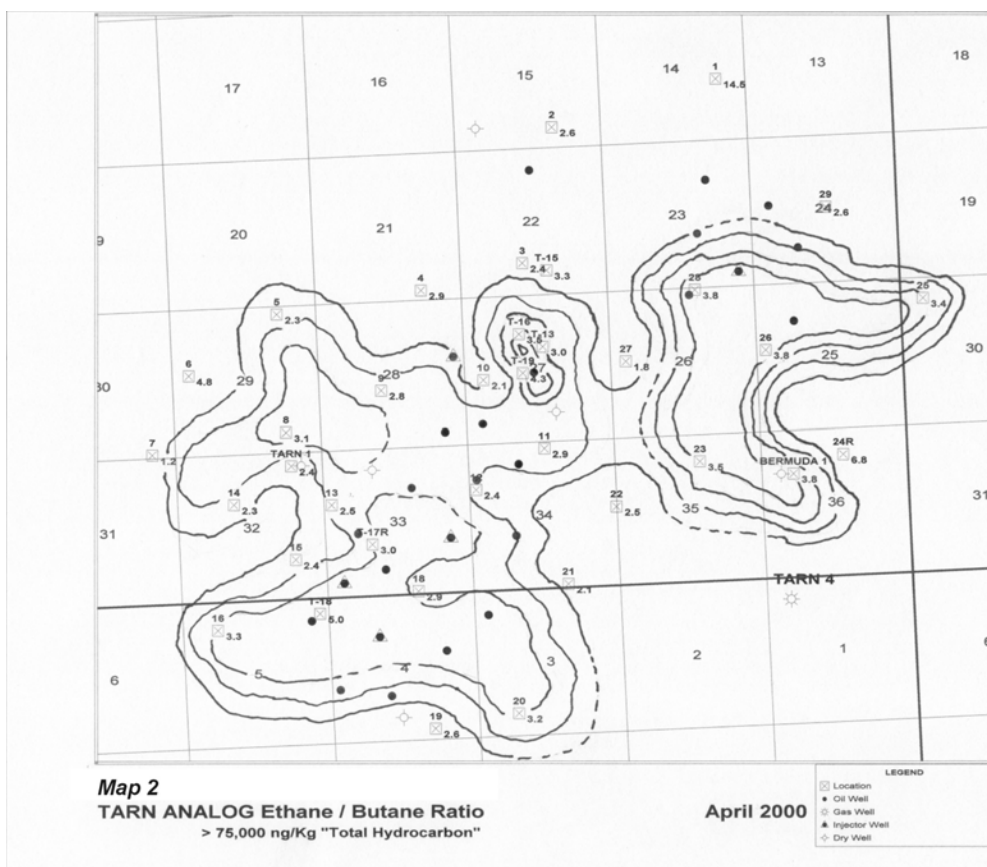
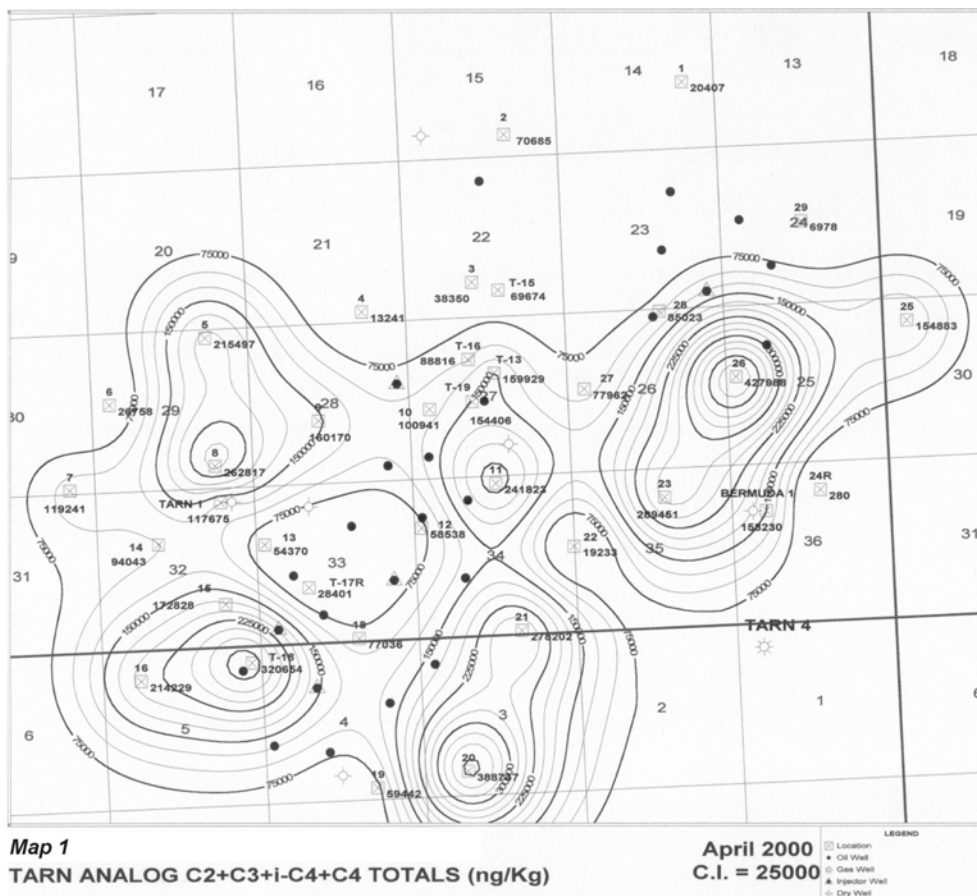
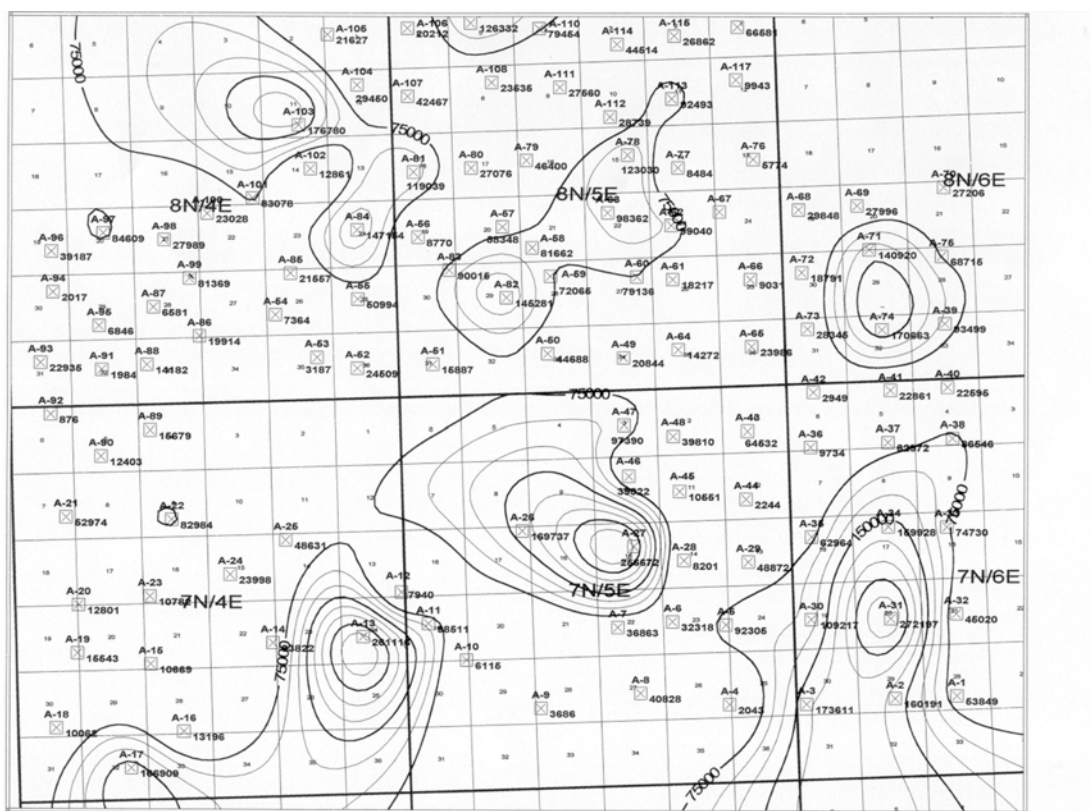


Figure 2 Pixler Families 1-4 L to R





Map 3  
Alaska Lease Sale - C2+C3+ic4+C4 Concentration ng/Kg

CI= 10,000  
May 2000

LEGEND  
X Sample Location

