PSOil Types of the Alaskan North Slope — A Progress Report*

P.G. Lillis¹, K.E. Peters², and L.B. Magoon²

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¹U.S. Geological Survey, Denver, CO, USA (plillis@usgs.gov)

²U.S. Geological Survey, Menlo Park, CA, USA

Abstract

Oil typing on the North Slope of Alaska has been a challenge for geochemists for more than 25 years because many of the oil accumulations are mixtures of oil types, and for some of the source formations, more than one oil type has been generated because of organic facies variation. A further complication is that crude oil composition is influenced by non-genetic effects, such as thermal maturity of the source rock at the time of expulsion, and biodegradation and cracking of the oil after expulsion. Significant progress has been made in recent years with a growing number of oil samples - using newer analytical techniques and chemometric analysis.

This study reviews the geological and geochemical interpretations from previous North Slope studies and presents recently acquired geochemical data to better identify and distinguish end-member and mixed oil types. At least ten end-member oil types have been identified. Probable source formations for the oil types include the Carboniferous-Permian Lisburne Group (includes the Kuna Formation), Triassic Shublik Formation, Triassic-Jurassic Otuk Formation, Jurassic-Cretaceous Kingak Shale, Cretaceous Torok Formation, pebble shale unit, and Hue Shale (includes the gamma ray zone or GRZ), and the Tertiary Canning Formation. Recognition and mapping of oil types provide the basis for defining and mapping petroleum systems that incorporate the geologic framework, source rock distribution, burial history, and migration pathways



Oil types of the Alaskan North Slope — a progress report

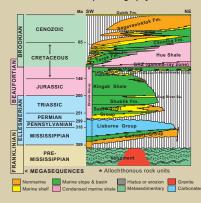
P.G. Lillis, K.E. Peters and L.B. Magoon U.S. Geological Survey, Denver, CO Menlo Park, CA

Abstract

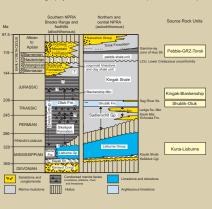
Oil typing on the North Slope of Alaska has been a challenge for geochemists for more than 25 years because many of the oil accumulations are mixtures of oil types, and for some of the source formations, more than one oil type has been generated because of organic facies variation. A further complication is that crude oil composition is influenced by non-genetic effects, such as thermal maturity of the source rock at the time of expulsion, and biodegradation and cracking of the oil after expulsion. Significant progress has been made in recent years with a growing number of oil samples - using newer analytical techniques and chemometric

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North Slope Stratigraphy



NPRA stratigraphy and oil source rock units (after Bird, 2002)



A Brief History of Previous Studies

The Lower Mississippian to Lower Permian Lisburne Group is widely distributed throughout the North Slope, and by Morgridge and Smith (1972) as a possible source of oil on consists predominantly of shallow marine carbonate rocks, but the North Slope. Subsequent studies have proposed that the locally consists of deep marine shale, chert, fine-grained lime- Kingak has contributed, in part, to Prudhoe Bay and other stone and dolomite. In the central and western Brooks Range the Lisburne Group consists predominantly of the deep marine Kuna Formation (Mull and others, 1982) and is generally organic-rich (Tailleur, 1964; Bird and Jordan, 1977; Magoon and Bird, 1988; Banet and Evans, 2002). The Lisburne has been proposed as an oil source rock by several workers (Bird and Jordan, 1977; Anders and others, 1985; Huang and others, 1985; Hughes and others, 1985; Keal and Dow, 1985; Magoon and Bird, 1988; GeoMark, 1997; Lillis and others, 1999; Holba, Wilson, and others, 2000, 2001; Masterson, 2001; Lillis of the Kingak Shale, and Bird (1994) combined the Blankenand others, 2002).

Lisburne are widely scattered and are few in number. Previous studies have proposed Lisburne source for oils from J.W. Dalton 1 (Hughes and others, 1985), KRU 2F-20 (Masterson 2001), Mikkelsen Bay State 1, South Barrow 12, South Barrow Pebble-GRZ-Torok-Hue Oil Types 17, and South Barrow 19 wells (GeoMark, 1997), and in oilstained outcrop in the northern foothills of the Brooks Range (Lillis and others, 2002). More recent geochemical studies suggest that the Barrow oils are derived from the Shublik (Holba, Ellis, and others, 2000).

Shublik and Otuk Oil Types

The Middle and Upper Triassic Shublik Formation is widely regarded as the source rock for the largest volume of petroleum on the North Slope of Alaska. Several oil fields, including the giant Prudhoe Bay field, contain a mixture of Shublik and other oil types (Seifert and others, 1980; Claypool and Magoon, 1985; Sedivy and others, 1987; GeoMark, 1997; Masterson, 2001). Oil in the Kuparuk field is predominantly derived from the Shublik Formation (Masterson and others, 1997, 2001; Masterson, 2001). Two Shublik oil sub-types, distal and proximal, also have been recognized (Holba and others, 2000: Masterson, 2001).

Formation in the central and western Brooks Range was renamed the Otuk Formation (Mull and others, 1982) and has been identified as the source rock for the oil found in outcrops Lillis and others, 1999; Holba and others, 2001). in the central Brooks Range Foothills (Lillis and others, 2002). Bird (1994) considered the chert and limestone members of the Canning Oil Type Otuk to be lateral time-stratigraphic equivalents to the Shublik in his characterization of the Ellesmerian petroleum system of the North Slope. Although the Shublik and Otuk were considered as a single source rock unit for the USGS 2002 resource assessment of the National Petroleum Reserve. Alaska or composition (Lillis and others, 2002) and lithology (Mull and core in the Aurora well. others, 1982) between the two formations

Kingak and Blankenship Oil Types

Jurassic marine shales (Kingak Shale) were first proposed Premuzac and others, 1986; Sedivy and others, 1987; GeoMark,1997; Holba, Wilson, and others, 2000, Masterson, 2001). Until Alpine field was discovered, only a few small oil accumulations (e.g., Kavearak 32-25, Milne Point field) with pure Kingak oil had been identified (Seifert and others, 1980;

The Blankenship Member of the Otuk Formation (Mull and others, 1982) is the southern, distal stratigraphic equivalent ship with the Kingak in his Ellesmerian petroleum system. Oil occurrences believed to be derived from the Kuna or Lillis and others (2002) correlated Blankenship source rocks to oil-stained outcrop in the northern foothills of the Brooks Range and noted similarities to Kingak oils from Alpine field.

Lower Cretaceous source rocks have long been recognized on the North Slope (Morgridge and Smith, 1972; Jones and Speers, 1976), and an early oil-source rock correlation study by Seifert and others (1980) showed that Lower Cretaceous post-Neocomian source rock is a significant contributor of oil to Prudhoe Bay field. This interval (the highly radioactive zone or HRZ) is also called the "gamma-ray zone" or GRZ (Tailleur and others, 1978) within the informally named pebble shale nit (Molenaar, 1981, 1983). The pebble shale unit has been differentiated from the GRZ within NPRA (Bird, 2002) and east of NPRA (Molenaar and others, 1987). The Lower Cretaceous Torok Formation lies above the GRZ and below the Cretaceous Nanushuk Group (Bird, 1985). In a multi-laboratory cooperative study (Claypool and Magoon, 1985), oil from Umiat field has been attributed to the pebble shale unit (14 labs) or the Torok (7 labs). Oil from Tarn field has been corre lated to the GRZ (Masterson, 2001).

Oils derived from the Hue Shale (includes GRZ) east of The age-equivalent strata originally mapped as the Shublik Kuparak field have a distinct composition and have been treated as a separate oil type (Anders and others, 1987; Sedivy and others, 1987; Wicks and others, 1991; GeoMark, 1997;

The Tertiary Canning oil type has been previously recognized in the Arctic National Wildlife Refuge (ANWR) area (Anders and others, 1987; GeoMark, 1997; Lillis and others, 1999; Holba and others, 2001), and includes oils from Man-NPRA (Lillis, 2003), there are noted differences in biomarker ning Point seep, Angun seep, Kuvlum field, and an oil-stained

Methods

roximately 110 new analyses were performed on key oils from previous studies, oils from recent discoveries, oil-stained core and outcrop, and oil seeps. Analyses include API gravity, sulfur content, column chromatography, stable carbon isotopes. gas chromatography (GC)-flame ionization detector, GC-mass trometry (MS), and GC-MS-MS. Results were divided into 2 iers based on sample and data quality, with tier 1 consisting of nondegraded oils. Correlation hierarchy consists of first grouping oils by bulk properties, then by molecular properties. To assist in orrelation multivariate statistical analysis (chemometrics) was erformed on tier 1, which became the training set for tier 2.

Objectives

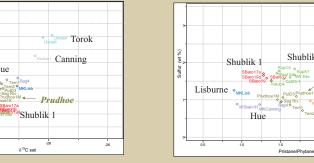
- -- Confirm end-member oil types from previous studies
- -- Characterize mixed oil types.
- Identify oil types of recent discoveries.
- Identify oil types in oil-stained core and seeps.

Results

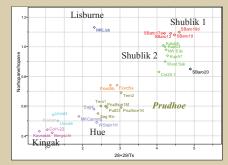
Tier 1 Samples -- nondegraded oils

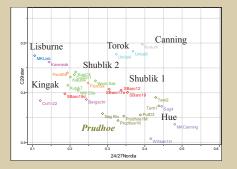
Oil types are first identified based on **bulk** properties: δ^{13} C saturated and aromatic hydrocarbon values, sulfur content, and pristane/phytane ratios.





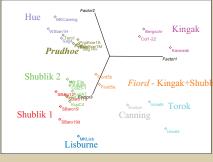
Molecular parameters (biomarkers) further refine oil types.

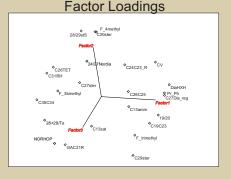


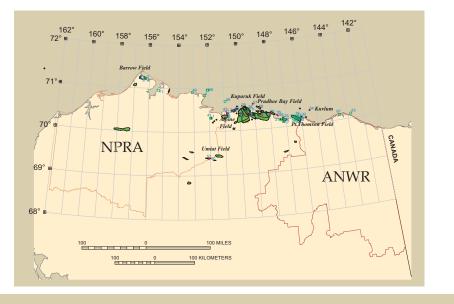


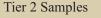
Principal component analysis (PCA) uses bulk and molecular parameters to further refine oil types.

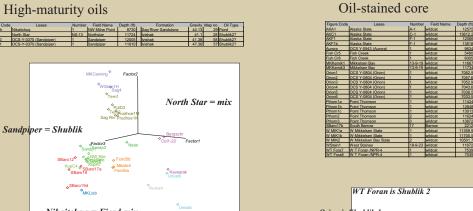
Factor Scores











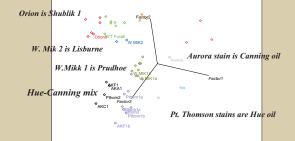
Manning = Cannin

Seismic = Toro

Degraded oils

Fish Creek = Shublik 2 %

S. Barrow20= nebble ?



Shublik1 and Shublik2 oils may be related to the distal and proximal Shubik oil types, respectively, of Holba and others (2000). The source of Shublik 1 oil type has lower clay content and was deposited in a more reducing environment based on the oils having higher norhopane/hopane and gammercerane/C31H ratios, and lower pristane/phytane, diahopane/hopane, and diasterane/sterane ratios than Shublik 2 oils.

Discussion

The chemical composition of Prudhoe Bay field more closely resembles the Hue oil type, suggesting that the majority of the oil migrated from eastern Hue/GRZ sources rather than the low-sulfur organic facies of GRZ to

Conclusions

Oil typing on the North Slope of Alaska continues to be a challenge for geochemists because many of the oil accumulations are mixtures of oil types (for example, Prudhoe Bay field). For the Shublik and GRZ source rock units (and probably others), more than one oil type has been generated because of organic facies

Based on a review of the geological and geochemical interpretations from previous North Slope studies and the results of this study, the following end-member and mixed oil types are distinguished:

<u>Field</u>

Kuvlum

Mikkelser Shublik 1 Barrow Shublik 2 Kuparak Kingak Hue (GRZ -east) Point Thomson GRZ -west*

Mixed oil types

Prudhoe = Hue/GRZ > Shublik 2 >> Kingak Fiord = Shublik and Kingak (about 50:50) Alaska State wells = Hue>Canning

*based on Masterson (2001

Oil analyses were performed by Augusta Warden, Michael Pribil, J. David King and Nicholas Battaglia at the USGS Organic Geochemistry Laboratory in Denver, Colorado. Map base was generated by Zenon Valin, USGS, Menlo Park, California. Stratigraphic columns were provided by Ken Bird, USGS, Menlo Park, California,