



Representative bulk composition of oil types for the 2002 U.S. Geological Survey Resource Assessment of National Petroleum Reserve in Alaska

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Abstract

Bulk oil composition is an important economic consideration of a petroleum resource assessment. Geological and geochemical interpretations from previous North Slope studies combined with recently acquired geochemical data are used to predict representative oil gravity ($^{\circ}$ API) and sulfur content (wt.% S) of the oil types for the 2002 U.S. Geological Survey resource assessment of the National Petroleum Reserve of Alaska (NPRA). The oil types are named after their respective source rock units and include Kuna-Lisburne, Shublik-Otuk, Kingak-Blankenship, and Pebble-GRZ-Torok. The composition of the oil (24° API, 1.6 wt.% S) in the South Barrow 12 well was selected as representative of Kuna-Lisburne oil. The average gravity and sulfur values (23° API and 1.6 wt.% S, respectively) of the Kuparuk field were selected to be representative of Shublik-Otuk oil type. The composition of the oil (39° API, 0.3 wt.% S) from the Alpine field discovery well (ARCO Bergschrund 1) was selected to be representative of Kingak-Blankenship oil. The oil composition (37° API, 0.1 wt.% S) of Tarn field was considered representative of the Pebble-GRZ-Torok oil type in NPRA.

Introduction

An important economic consideration of a petroleum resource assessment is the bulk composition of the petroleum charge in the assessment unit or play, especially its specific gravity and sulfur content. For example, crude oil with high API gravity (American Petroleum Institute gravity scale in $^{\circ}$ API) and low sulfur content (wt.% S) has more economic value than low API gravity, high sulfur oil. The geochemical composition of oil is controlled by the kerogen composition of the source rock as well as by post-expulsion alteration effects such as biodegradation and thermal cracking. Therefore, it is critical to identify and map the source rock for an assessed play and characterize the composition of the hydrocarbon charge. This report incorporates geological and geochemical interpretations from previous North Slope studies (Magoon and Claypool, 1981, 1988; Hughes and Holba, 1988; GeoMark, 1997; Sedivy and others, 1987; Lillis and others, 1999; Threlkeld and others, 2000; Masterson, 2001) with recently acquired geochemical data to predict a representative bulk composition of the oil types for the 2002 U.S. Geological Survey (USGS) resource assessment plays of the National Petroleum Reserve of Alaska (NPRA).

Oil source rocks recognized in NPRA as being important for this assessment include, from oldest to youngest, Kuna Formation, Lisburne Group, Shublik Formation, Otuk Formation, Kingak Shale, pebble shale unit, gamma ray zone (GRZ) and Torok Formation (fig. 1). These units contain oil-prone kerogen and have been correlated with oil accumulations or oil-stained rocks in the area (fig. 2). For the 2002 resource assessment, rock units known to be widely distributed in the NPRA (Lisburne, Shublik, and Kingak) have been considered along with their distal, condensed equivalents (Kuna, Otuk, and Blankenship, respectively) that are

present in the Brooks Range and foothills of southern NPRA (see Bird, this volume). These stratigraphic units with similar age and kerogen composition are referred to in this assessment by hyphenated source rock names: Kuna-Lisburne, Shublik-Otuk, Kingak-Blankenship, and Pebble-GRZ-Torok; the geologic and geochemical rationale for these combinations is discussed further below. The Hue Shale and Canning Formation are located too far away to be considered source rocks for oil within NPRA, but they are effective source rocks east of Prudhoe Bay (Lillis and others, 1999). Coal within the Kekiktuk Conglomerate is likely to be only a source for gas and will not be discussed further.

This report assigns the representative bulk composition of the oil types based on the data of crude oil interpreted to be derived from a single source rock unit. However, oil-source rock correlation on the North Slope is more difficult because of mixed oil types and variation in organic facies within a source formation. 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. All these effects must be recognized and taken into account when assigning a representative bulk composition.

For each play of the 2002 NPRA assessment, the assessment geologist determined (1) the mostly likely source of oil based upon the distribution of thermally mature source rock, (2) the time of oil generation with respect to the time of trap formation, and (3) whether favorable “plumbing” geometry existed at the time when oil migrated into the play area. Each of the 16 oil plays was thus assigned an API gravity and sulfur content based on the expected oil type. When more than one oil type is predicted in a play, then the assigned API gravity and sulfur content reflect the mixture of the end member types.

Kuna-Lisburne source rock unit

The Lower Mississippian to Lower Permian Lisburne Group is widely distributed throughout the North Slope, and consists predominantly of shallow marine carbonate rocks, but locally consists of deep marine shale, chert, fine-grained limestone and dolomite. North of the Brooks Range (fig. 2) the Lisburne is predominantly platform carbonates low in organic carbon content with sporadic interbeds of organic-rich shale (Masterson, 2001). 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 and others, 2002), and work in progress by the USGS (Lillis, unpublished data) shows that the shale facies is likely the primary oil source. The Kuna-Lisburne is here designated a source rock unit because the Kuna Formation as well as other unnamed thin beds of organic-rich source rocks are within the Lisburne Group.

Oil occurrences believed to be derived from the Kuna-Lisburne source rock unit are widely scattered and few in number. The only oil samples of Kuna-Lisburne for which there are API gravity and sulfur data are from the J.W. Dalton 1, KRU 2F-20, Mikkelsen Bay State 1 South Barrow 12, South Barrow 17, and South Barrow 19 wells (fig. 2, table 1). However,

there are problems connected with each of these samples. The oil gravity and sulfur content of the Dalton sample has been altered by biodegradation (Magoon and Claypool, 1988) and the KRU 2F-20 sample was generated at high maturity (Masterson, 2001). The Mikkelsen well is located the farthest from NPRA, and may have a slightly different oil composition because of possible lateral source facies variation within the Kuna-Lisburne. The South Barrow oil samples were proposed to be Kuna-Lisburne oils (GeoMark, 1997) but more recent geochemical studies suggest that they are derived from the Shublik-Otuk source rock unit (Holba, Ellis, and others, 2000). Consequently, the gravity and sulfur content of Kuna-Lisburne type oil estimated for the assessment has a higher degree of uncertainty than the other oil types. For the assessment, the composition of the South Barrow 12 oil (24°API, 1.6 wt.% S) was selected as representative of Kuna-Lisburne oil (table 1).

Shublik-Otuk source rock unit

The Shublik-Otuk source rock unit includes the widespread Shublik Formation and the chert and limestone members of the Otuk Formation in the central and western Brooks Range. 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. Many of the 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), so the oil composition of these fields is not wholly representative of the Shublik-Otuk oil type. However, oil in the Kuparuk field (fig. 2) is predominantly derived from the Shublik Formation (Masterson and others, 1997, 2001; Masterson, 2001). Accordingly, the gravity and sulfur values used for this assessment are 23°API and 1.6 wt.% S, respectively, based on the average composition of Kuparuk field (table 2).

The age-equivalent strata originally mapped as the Shublik 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 in the central Brooks Range Foothills (Lillis and others, 2002). Bird (1994) considered the chert and limestone members of the Otuk to be lateral time-stratigraphic equivalents to the Shublik in his characterization of the Ellesmerian petroleum system of the North Slope. Similarly, the Shublik and Otuk are considered here as a single source rock unit following the same rationale, although there are noted differences in biomarker composition (Lillis and others, 2002) and lithology (Mull and others, 1982) between the two formations.

Kingak-Blankenship source rock unit

The Kingak-Blankenship source rock unit includes the widespread Kingak Shale and the partly age-equivalent Blankenship Member of the Otuk Formation in the Brooks Range. Jurassic marine shales (Kingak Shale) were first proposed by Morgridge and Smith (1972) as a possible source of oil on the North Slope. Seifert and others (1980) presented geochemical evidence that the Kingak Shale is the source rock for oil recovered from a drill-stem test from the Kavarak 32-25 well (Milne Point field) and that the Kingak is a significant oil contributor to Prudhoe Bay field (fig. 2). This interpretation has been supported by subsequent studies (Claypool and Magoon, 1985; 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 with pure Kingak oil had been identified (GeoMark, 1997). Because Alpine field is the largest known accumulation of Kingak oil (Masterson, 2001) and is located adjacent to NPRA, the gravity and sulfur content (39° API, 0.3 wt.% S) of the oil from the discovery well (ARCO Bergschrund 1) were used for this assessment as representative of Kingak-Blankenship oil (table 2).

The Blankenship Member of the Otuk Formation (Mull and others, 1982) is the southern, distal stratigraphic equivalent of the Kingak Shale, and Bird (1994) combined the Blankenship with the Kingak in his calculations of the Ellesmerian petroleum system. Work in progress at the USGS (Lillis, unpublished data) shows that the Blankenship bitumen extract composition is very similar to the oil derived from the Kingak Shale. Therefore, the Blankenship is combined with the Kingak as a single source rock unit.

Pebble-GRZ-Torok source rock unit

The Pebble-GRZ-Torok source rock unit includes a stack of three closely related Lower Cretaceous organic-rich rock units, the pebble shale unit (Pebble), the gamma-ray zone (GRZ), and the lower part of the Torok Formation. 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. These post-Neocomian strata were interpreted by Carmen and Hardwick (1983) to be the “highly radioactive zone” or HRZ (also called the “gamma-ray zone” or GRZ, Tailleur and others, 1978) within the informally named pebble shale unit (Molenaar, 1981, 1983). The pebble shale unit has been differentiated from the GRZ within NPRA (Bird, this volume) and east of NPRA (Molenaar and others, 1987). Work in progress at the USGS indicates that the pebble shale unit may be a potential source of oil in northeastern NPRA. The Lower Cretaceous Torok Formation lies above the GRZ and below the Cretaceous Nanushuk Group (Bird, 1985) and is most likely a source rock of oil (and gas) in NPRA (Magoon and Bird, 1985; Connan and others, 1985, Lillis and others, 2002).

Following previous studies (Claypool and Magoon, 1985; GeoMark, 1997), the pebble shale unit, GRZ, and Torok source rock intervals are here considered a single source rock unit because this conformable package of Lower Cretaceous strata has a similar kerogen composition (Magoon and Bird, 1988), and is likely to produce a similar low sulfur (0.1 wt.% S) oil. However, oil derived from the GRZ part of the Hue Shale east of NPRA has a higher sulfur content (0.5 to 1.0 wt.% S) (Lillis and others, 1999). The largest known accumulation of Pebble-GRZ-Torok oil is Tarn field (Masterson, 2001) and the bulk composition (37° API, 0.1 wt.% S) was considered representative for this source rock unit in NPRA (fig. 2, table 2).

Mixed oil types

For some of the plays of the 2002 NPRA assessment, the assessment geologist predicted more than one oil type. In these cases a representative bulk composition was based on a 50:50 mix of two end-member oil types (table 2). For example, a mixture of Shublik-Otuk

and Pebble-GRZ-Torok oil types is considered to have a gravity of 30°API and a sulfur content of 1.0 weight percent S.

Summary

This report assigns a representative gravity and sulfur content of the NPRA oil types predicted to charge the plays in the 2002 NPRA resource assessment. The oil types are believed to be derived from source rock units known to be widely distributed in the NPRA (Lisburne, Shublik, and Kingak) and their distal, condensed equivalents (Kuna, Otuk, and Blankenship, respectively). The oil types are named after their respective source rock units and include Kuna-Lisburne, Shublik-Otuk, Kingak-Blankenship, and Pebble-GRZ-Torok.

The largest known accumulation of each oil type (except Kuna-Lisburne) was selected as the representative composition. The average gravity and sulfur values of Kuparak field (23°API and 1.6 wt.% S) were considered to be representative of the Shublik-Otuk oil. The composition of the oil from the discovery well of Alpine field (39°API, 0.3 wt.% S) was used for the assessment as representative of Kingak-Blankenship oil. The composition (37°API, 0.1 wt.% S) of Tarn field was considered to be representative for Pebble-GRZ-Torok oil in NPRA. The composition of the South Barrow 12 oil (24°API gravity, 1.6 wt.% S) was selected as representative of Kuna-Lisburne oil.

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Table 1. API gravity and sulfur content of oil derived from Kuna-Lisburne source rock unit.

Well	Gravity (°API)	Sulfur (wt.%)	Data Source
J.W. Dalton 1	13	2.5	Magoon and Claypool (1988)
KRU 2F-20	33	0.7	Masterson (2001)
Mikkelsen Bay State 1	25	1.4	Lillis and others (1999)
S. Barrow 12	24	1.6	GeoMark (1997)
S. Barrow 17	19	1.9	Magoon and Claypool (1988)
S. Barrow 19	21	1.7	Magoon and Claypool (1988)

Table 2. API gravity and sulfur content of oil types used in the 2002 NPRA assessment.

Source rock unit	Gravity (°API)	Sulfur (wt.%)	Data source
Kuna-Lisburne	24	1.6	GeoMark (1997)
Shublik-Otuk	23	1.6	Masterson (2001)
Kingak-Blankenship	39	0.3	Masterson (2001)
Pebble-GRZ-Torok	37	0.1	Masterson (2001)
Shublik-Otuk <i>and</i> Pebble-GRZ-Torok (50:50 mix)	30	1.0	
Shublik-Otuk <i>and</i> Kingak-Blankenship (50:50 mix)	30	1.0	

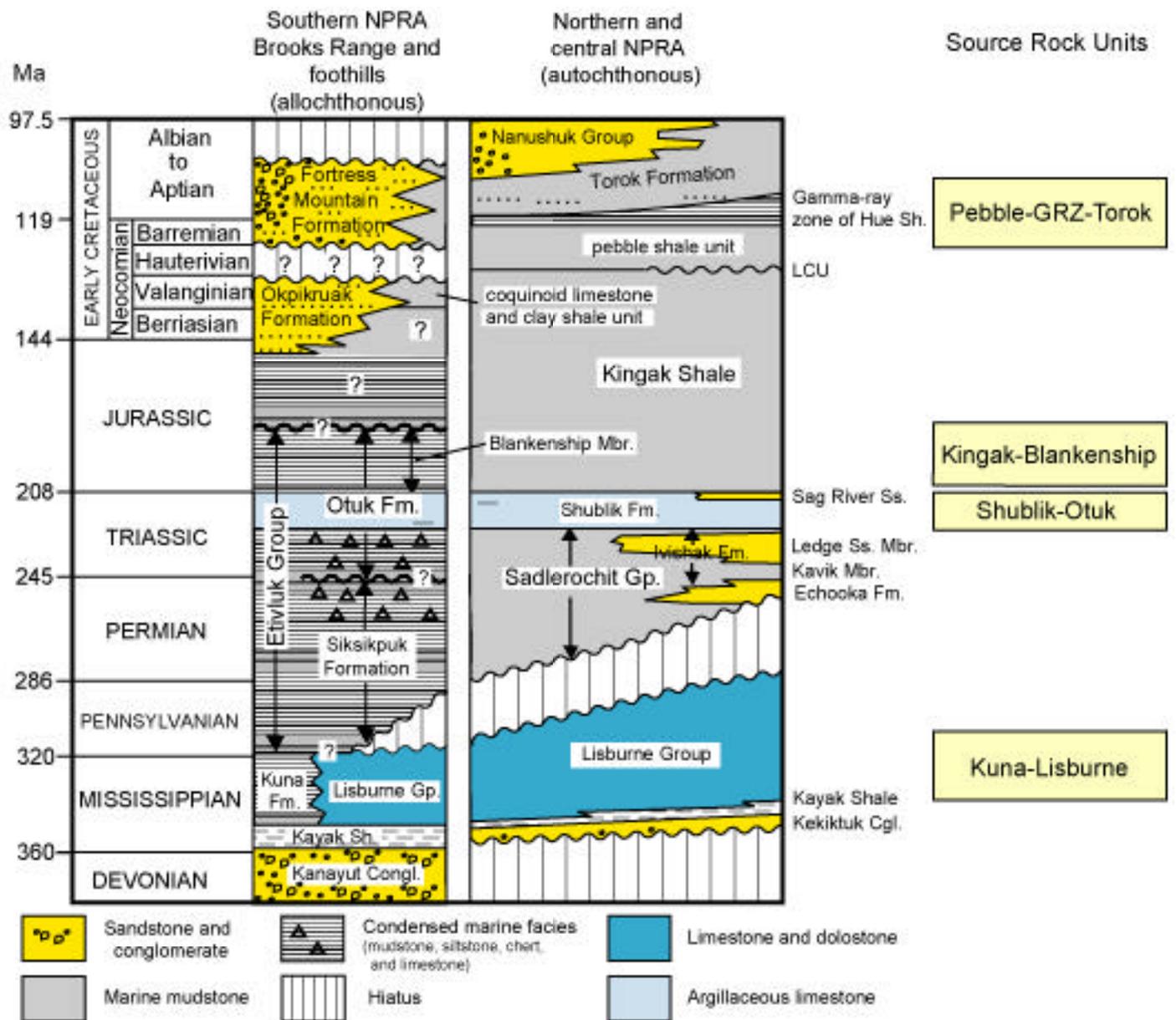


Figure 1. Stratigraphic summary of NPRA (modified from Bird, this volume), and oil source rock units used in the 2002 assessment. LCU, Lower Cretaceous unconformity.

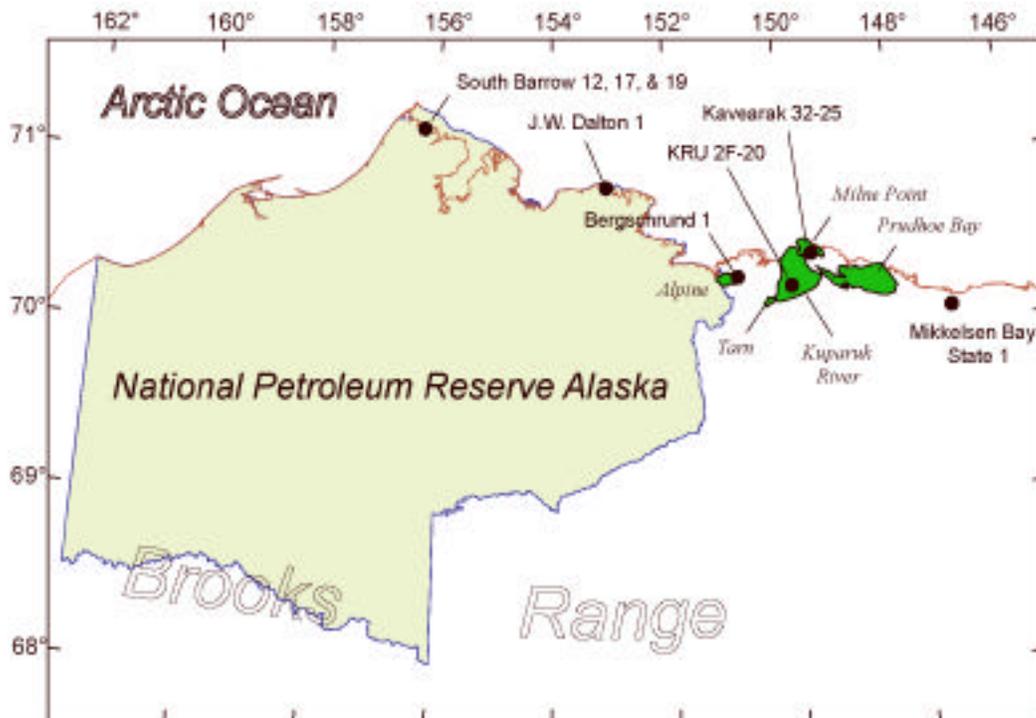


Figure 2. Index map of the National Petroleum Reserve Alaska (NPRA). Oil fields (green areas) and well locations (black dots) discussed in text.