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Distribution, Richness, Quality, and Thermal Maturity of Source Rock Units on the North Slope of Alaska

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ABSTRACT

Four source rock units on the North Slope were identified, characterized, and mapped to better understand the origin of petroleum in the area: Hue-gamma ray zone (Hue-GRZ), pebble shale unit, Kingak Shale, and Shublik Formation. Rock-Eval pyrolysis, total organic carbon analysis, and well logs were used to map the present-day thickness, organic quantity (TOC), quality (hydrogen index, HI), and thermal maturity (Tmax) of each unit. To map these units, we screened all available geochemical data for wells in the study area and assumed that the top and bottom of the oil window occur at Tmax of ~440º and 470ºC, respectively. Based on several assumptions related to carbon mass balance and regional distributions of TOC, the present-day source rock quantity and quality maps were used to determine the extent of fractional conversion of the kerogen to petroleum and to map the original organic richness prior to thermal maturation.

INTRODUCTION

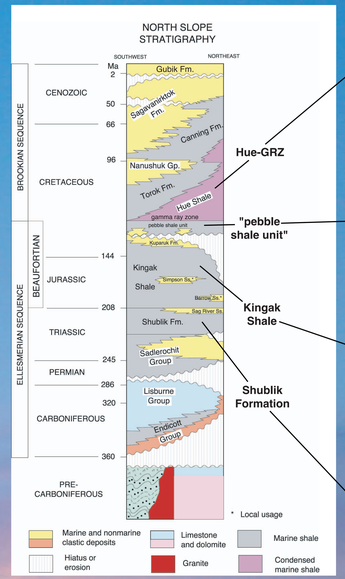
The North Slope of Alaska is a prolific oil and gas province partly due to the occurrence of multiple effective source rock units (Bird, 2001). In anticipation of our 3-dimensional computerized petroleum system modeling of this area using PetroMod (IES; Integrated Exploration Systems), we recognized the need for regional maps of organic richness prior to thermal maturation for each source rock unit. The study area is indicated by the polygon shape of the maps. Preparation of these maps required interpretation of available geochemical data from more than 60 North Slope wells.

METHODS

The tables (right) summarize wells that have geochemical data within the penetrated Hue-GRZ, pebble shale, Kingak, or Shublik source rocks, respectively. Thickness was determined from well logs (see Keller and Bird, this session). The number of samples (n) analyzed for Rock-Eval pyrolysis/TOC within each unit spans a depth range that accounts for a proportion of the total thickness of the unit (%Sampled). The thermal maturity of the source rock in each well was determined using average measured Tmax and production index (PI) (Peters, 1986), supplemented by comparison to vitrinite reflectance data. Original HI for mature and spent intervals was estimated by comparison to the measured HI of immature equivalents; using an east-west calibration (Hue-GRZ) or the average of the HI in immature equivalents of that interval from the two nearest wells. The original TOC (TOCo) and fractional conversion of kerogen to petroleum (f) for mature and spent units was calculated using mass balance and two assumptions: (1) the original PI (PIo) was equal to measured PI (PIx), and (2) the original hydrogen index (HIo) was equal to the average measured HI (HIx) for all immature samples of the source rock. With a few exceptions that can be explained, f increases systematically with increasing Tmax, suggesting that the calculations are reasonable.

Map shows location of study area (PetroMod Polygon).

RESULTS



Stratigraphy shows the four principal source rock units in this study (modified from Bird, 2001).

Hue-GRZ Well	Thickness (ft.)	Maturity	n	%sampled	Kerogen	Tmax	PI	TOC	HI	HIo	TOCo	f
Cape Simpson 1	70	immature	3	1.7	oil	428	0.08	2.04	44		2.21	
Gwyd Bay 1	50	immature	2	1.2	oil	428	0.08	2.04	44		2.21	
Kaktovik 1	50	immature	2	1.2	oil	428	0.08	2.04	44		2.21	
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Fiord 1	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Kuparuk 1	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
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Alaska State A-1	90	immature	4	2.2	oil	428	0.08	2.04	44		2.21	
Oumalik 1	90	immature	4	2.2	oil	428	0.08	2.04	44		2.21	
Sag River St. 1	90	immature	4	2.2	oil	428	0.08	2.04	44		2.21	
Tarn 2	90	immature	4	2.2	oil	428	0.08	2.04	44		2.21	
Colville 2	90	immature	4	2.2	oil	428	0.08	2.04	44		2.21	
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Fiord 3	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Kuparuk 4	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Prince Creek 4	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tulugak 4	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Ikpikpuk 4	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tunalik 4	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Fiord 4	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Kuparuk 5	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Prince Creek 5	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tulugak 5	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Ikpikpuk 5	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tunalik 5	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Fiord 5	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Kuparuk 6	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Prince Creek 6	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tulugak 6	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Ikpikpuk 6	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tunalik 6	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Fiord 6	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Kuparuk 7	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Prince Creek 7	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tulugak 7	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Ikpikpuk 7	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tunalik 7	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Fiord 7	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Kuparuk 8	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Prince Creek 8	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tulugak 8	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Ikpikpuk 8	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tunalik 8	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Fiord 8	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Kuparuk 9	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Prince Creek 9	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tulugak 9	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Ikpikpuk 9	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tunalik 9	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Fiord 9	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Kuparuk 10	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Prince Creek 10	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tulugak 10	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Ikpikpuk 10	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Tunalik 10	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	
Fiord 10	110	immature	5	2.7	oil	428	0.08	2.04	44		2.21	

Shublik Well	Thickness (ft.)	Maturity	n	%sampled	Kerogen	Tmax	PI	TOC	HI	HIo	TOCo	f
Cape Simpson 1	270	immature	16	6.2	oil	428	0.08	2.04