U.S. DEPARTMENT OF THE INTERIOR
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Petroleum Systems of the Alaskan North Slope - A Numerical Journey from Source to Trap

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INTRODUCTION

The complex petroleum province of the Alaskan North Slope contains six petroleum systems (Magoon and others, this session). Source rocks for four of these systems include the Hue-gamma ray zone (Hue-GRZ), pebble shale unit, Kingak Shale, and Shublik Formation. Geochemical data for these source rocks are investigated in greater detail and provide the basis for numerical petroleum migration models.

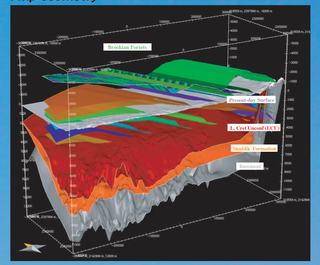
Diachronous deposition (progradation) of the overlying Brookian sequence from west (120 Ma) to east (33 Ma) resulted in western and eastern depocenters, where each source rock became mature at two different times. The diachronous deposition, combined with the changing geometry of the system, resulted in a complicated petroleum migration history involving multiple petroleum systems.

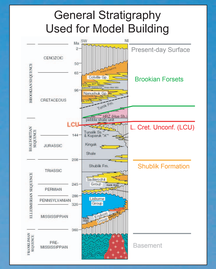
OBJECTIVES

- What were the distributions of active source rocks through time and today?
- When did the critical moments occur for each source rock?
- What are the generalized pathways for petroleum migration?

INPUT

Map Geometry

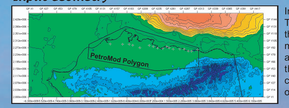




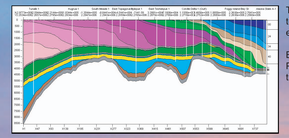
modified from Bird (2001)

Layered surfaces are the basis for the 3D model. Surfaces are derived from seismic and well data and input using Zmap (seismic 3D maps) and Arc/Info (foresets). Rather than using a stratigraphic subdivision of the Brookian section, timelines of prograding foresets were mapped to allow for a time-transgressive change of geometry. See poster by Peters and others, this session.

Input Geometry



Input data set of the 3D model. The PetroMod polygon depicts the position and shape of the 3D model. The 2D cross section along the key wells is cut from the 3D input model and coincides with the Molenaar and others section (1986).

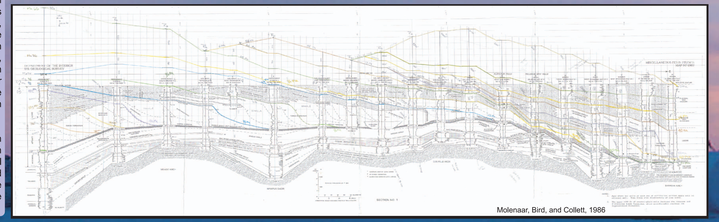


Top = bathymetry and surface topography showing wells on east-west transect

Botttom = present day 2D PetroMod view along east-west transect

Molenaar and others 2D cross section along W-E trending key wells served as a basis to reconstruct the shape, thickness and eroded thickness of the prograding foresets in the Brookian section. The pre-erosional thickness, i.e., maximum burial depth, for each foreset was determined using a linear extrapolation of measured vitrinite reflectance on semilog scale from each well.

The reconstructed lost overburden reaches up to ~4000 m in the western part of the section. This erosional thickness controls the burial depth and thermal maturity history of the source rocks as well as the geometry of the migration paths.



Molenaar, Bird, and Collett, 1986

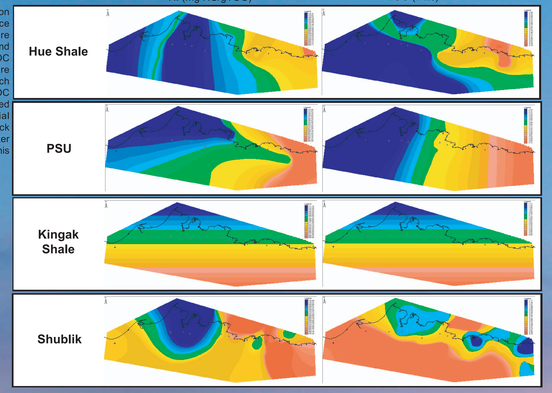
Input Parameters

Input parameters (lithology, age, and source rock properties) for the layers featured in the 3D model.

Layer	Top Age [Ma]	Lithology	Kinetic Reaction	TOC	HI	Component Oil	Component Gas
Foreset-sand	110 - 0	SANDSTONE					
Foreset-shale	110 - 0	SHALE					
Hue-GRZ	119	SHALE	Hue_Lillis (Type II)	TOC-hue	HI-hue	Hue-GRZ_LightOil	Hue-GRZ_WetGas
PSU	122	SHALE	HRZ_Masterson (Type II)	TOC-pebble	HI-pebble	PSU_LightOil	PSU_WetGas
LCU-Kemik	125	SANDSTONE					
Kuparuk	126	SANDSTONE					
Kingak	127	SHALEsand					
Kingak-sr	198	SHALE	Kingak_Masterson (Type II)	TOC-kingak	HI-kingak	Kingak_LightOil	Kingak_WetGas
SagRiver	205	SANDSTONE					
Shublik	208	LIMEshaly	Shublik_Lillis (Type II)	TOC-shublik	HI-shublik	Shublik_MediumOil	Shublik_Methane
Ledge	220	SANDSTONE					
Lisburne	260	LIMEdolom					
Endicott	300	SHALE&SILT					
Basement	350	BASEMENT					

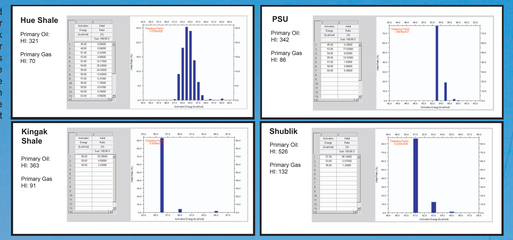
Source Rock Properties

HI and TOC distribution throughout the source rock layers. Values are based on measured and contoured HI and TOC from key wells and are extrapolated for each map. Both HI and TOC were adjusted/calculated to represent initial unspent source rock parameters. (see poster by Peters and others, this session).



Source Rock Kinetics

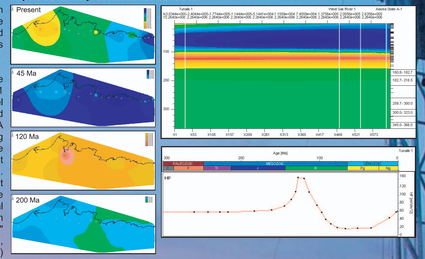
Primary oil and gas reactions for the source rock kinetics after Lillis and others (1999) for the Shublik and Hue and Masterson (2001) for the pebble shale unit and Kingak.



Input Boundary Conditions: Heat Flow

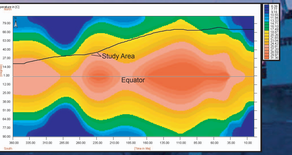
The heat flow maps (left) and the cross section (upper right, both given in mW/m²) show the general heat flow distribution both in space and time. Note that the vertical-axis of the cross section shows time!

Heat flow trends (through time) were determined in 1D sensitivity studies (Tunalik-1 well) and are based on calibration of the model to measured vitrinite reflectance and corrected bottom hole temperatures from key wells. A heat flow peak occurs at ~120 Ma, coinciding with the rifting/rotation of the Alaskan plate away from the Canadian plate. The subsequent cooling reaches a minimum at around 45 Ma. This general trend is shown at the lower right by the heat flow assumed for well Tunalik. The spatial heat flow distribution suggests a local "high" in the vicinity of the Kugrua, South Meade and Topagoruk (West) wells and a "low" in the vicinity of the Nechelik, Colville Delta, Kalubik Creek and West Sak River (East) wells.



Input Boundary Conditions: Sediment-Water Interface Temperature

Automatic calculation of sediment-water-interface temperature (SWIT) through time. This trend accounts for continental movements and climate variations. The temperature values are subsequently corrected for water depth, i.e., 4000 m of water depth would result in a SWIT of 4 C regardless of latitude. Calculation is based on the present-day position of the study area (North America, 70 N) (Wygrala, 1989)



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