Integrated Geological and Engineering Studies in Support of Producing Light Oil from a Frozen Reservoir: A Case Study from Umiat Oil Field, Northern Alaska*

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Abstract

Shallow oil production in arctic regions must contend with a variety of unique production issues. Consolidated reservoirs in the permafrost may have production challenges even if the oil is light and not biodegraded. While deemed uneconomic in the past, horizontal drilling technology and higher oil prices may make these shallow accumulations economic if the reservoir character and rock and fluid behavior under these low temperature and pressure conditions are adequately understood and managed.

The Umiat field of the National Petroleum Reserve of Alaska (NPRA) is an example of such a shallow, light oil accumulation. Umiat is a thrust-related anticline at the leading edge of the Brooks Range fold-and-thrust belt and consists of multiple reservoirs in shallow marine clastic rocks of the Cretaceous Nanushuk Formation. Most of the potential reservoir rocks are within permafrost. Natural fractures associated with the folding may impart a permeability anisotropy to the reservoir. If so, these fractures could be utilized to enhance production by selective well placement and orientation. Ongoing reservoir modeling attempts to capture both sedimentologic and structural reservoir heterogeneities and predict how the Umiat reservoir will flow using horizontal wells with pressure maintenance by cold gas injection.

Reservoir modeling also requires an understanding of how Umiat rock and fluids will behave in the presence of ice. Gas-oil relative permeability analysis on Umiat core plug samples indicate a clear reduction in the relative permeability of gas and oil in the presence of *in situ* ice. In order to more fully evaluate what part of the reservoir will experience this reduction, NMR analysis of water-saturated and frozen Umiat samples is underway in order clarify where ice forms and at what temperature at various reservoir depths.

No live Umiat oil samples exist. Recent density and viscosity analysis of a dead Umiat oil sample yielded an API gravity of ~30°, a value significantly lower than the 37° API gravity reported when the field was discovered in the 1940's. This suggests that the sample has been extensively weathered, and its characteristics are not totally representative of the original oil. In order to determine a representative Umiat fluid for reservoir simulation, the recent analytical results will be used to calibrate an Equations of State (EOS) model that will then be used to predict the properties of a representative Umiat fluid.

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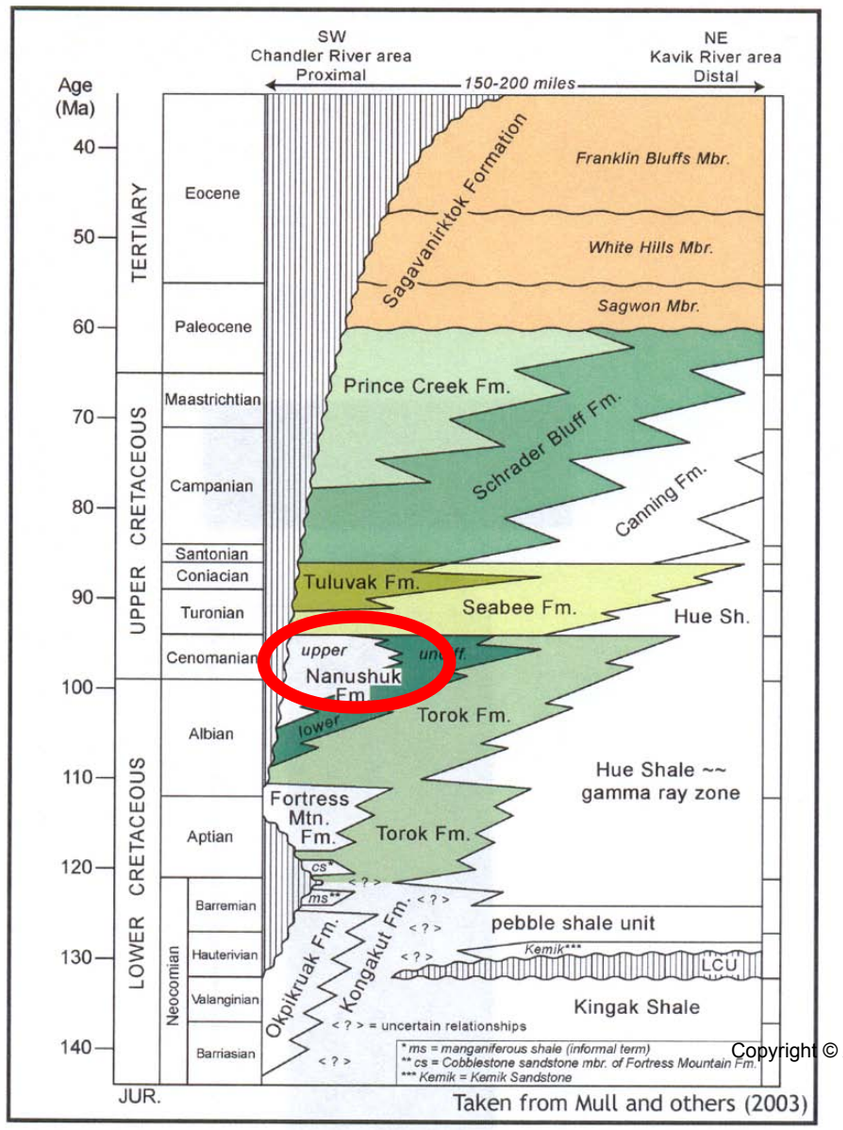
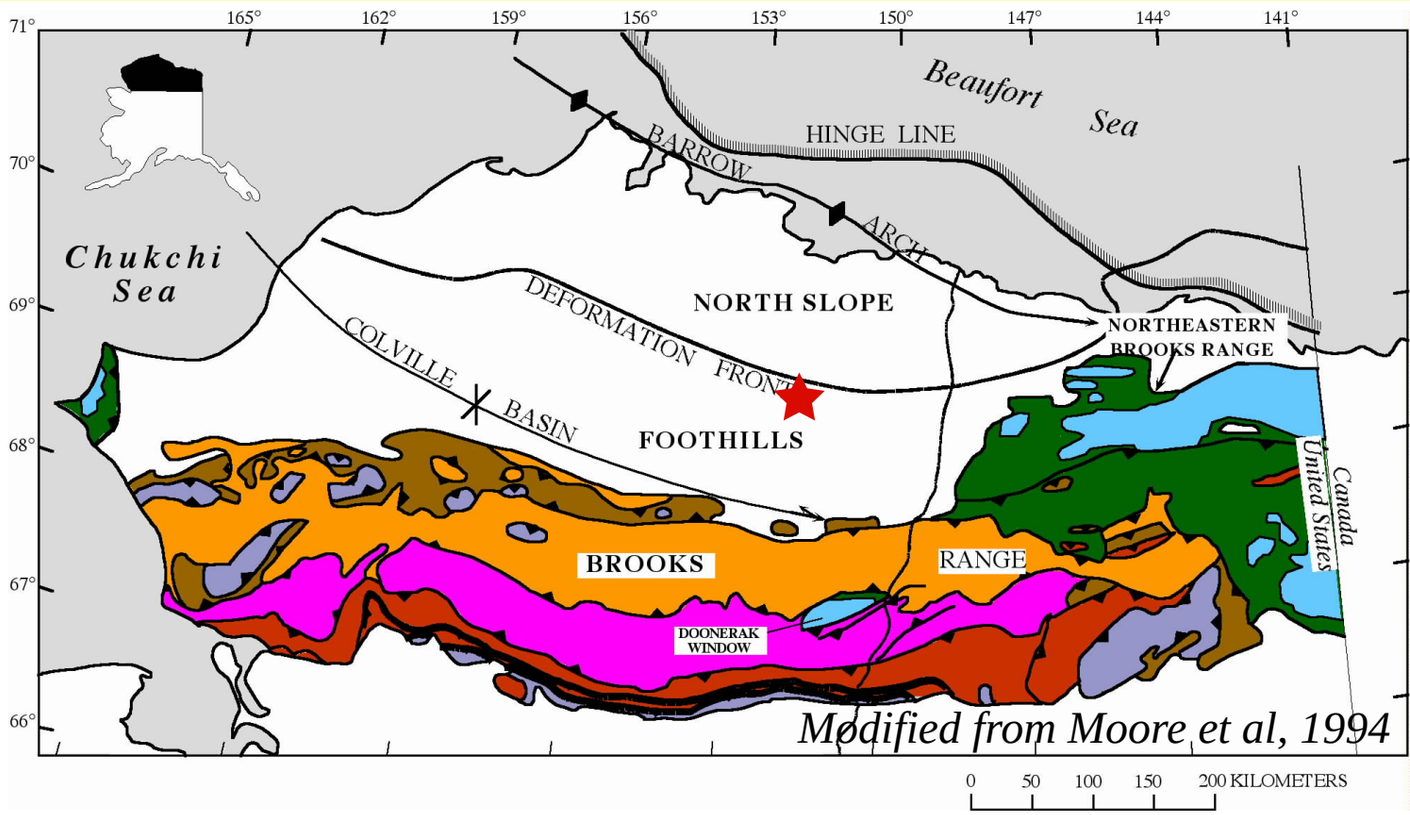
Location of Umiat field

Geologic setting

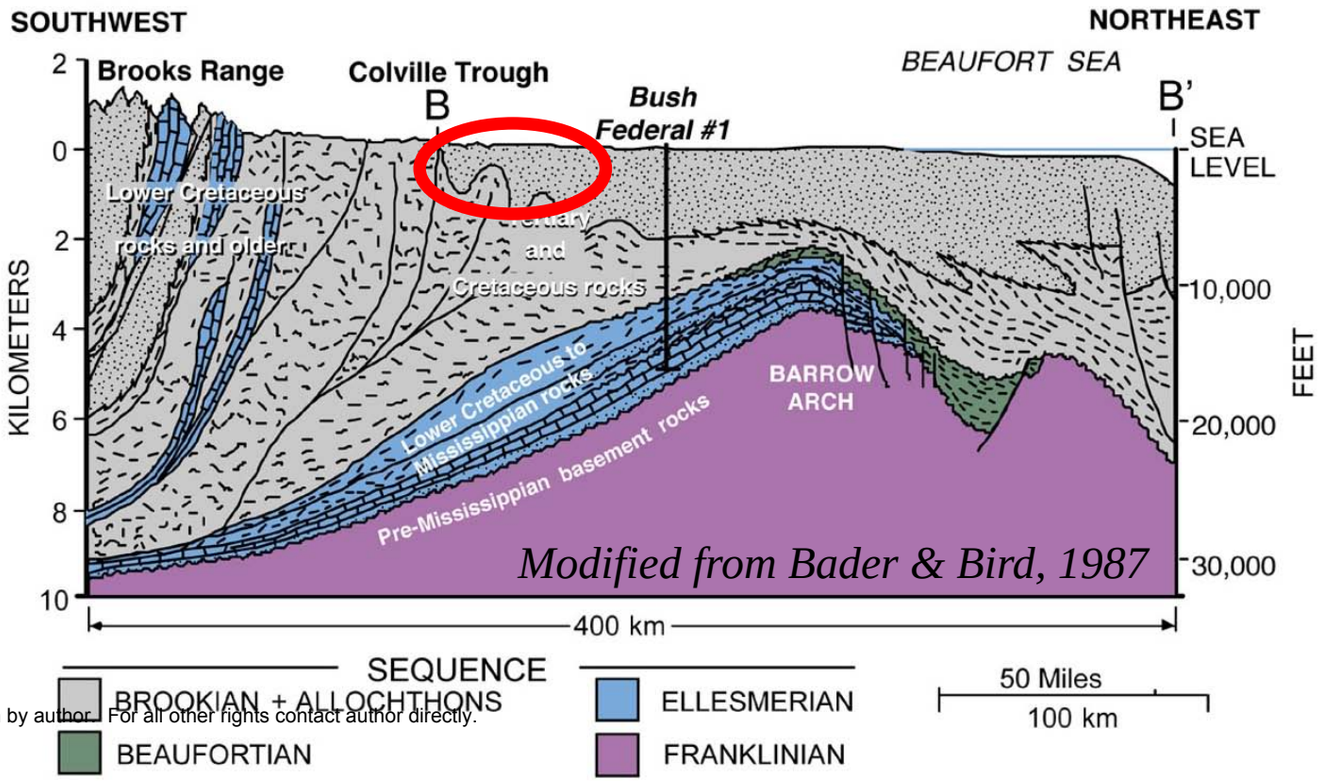
Umiat field is a thrust-related anticline in foredeep deposits at the leading edge of the Brooks Range



Taken from Mull and others (2003)



Modified from Moore et al, 1994



Modified from Bader & Bird, 1987

Umiat Field

Discovered: 1946

Oil gravity: 36-37°API

Area: 7,500 acres

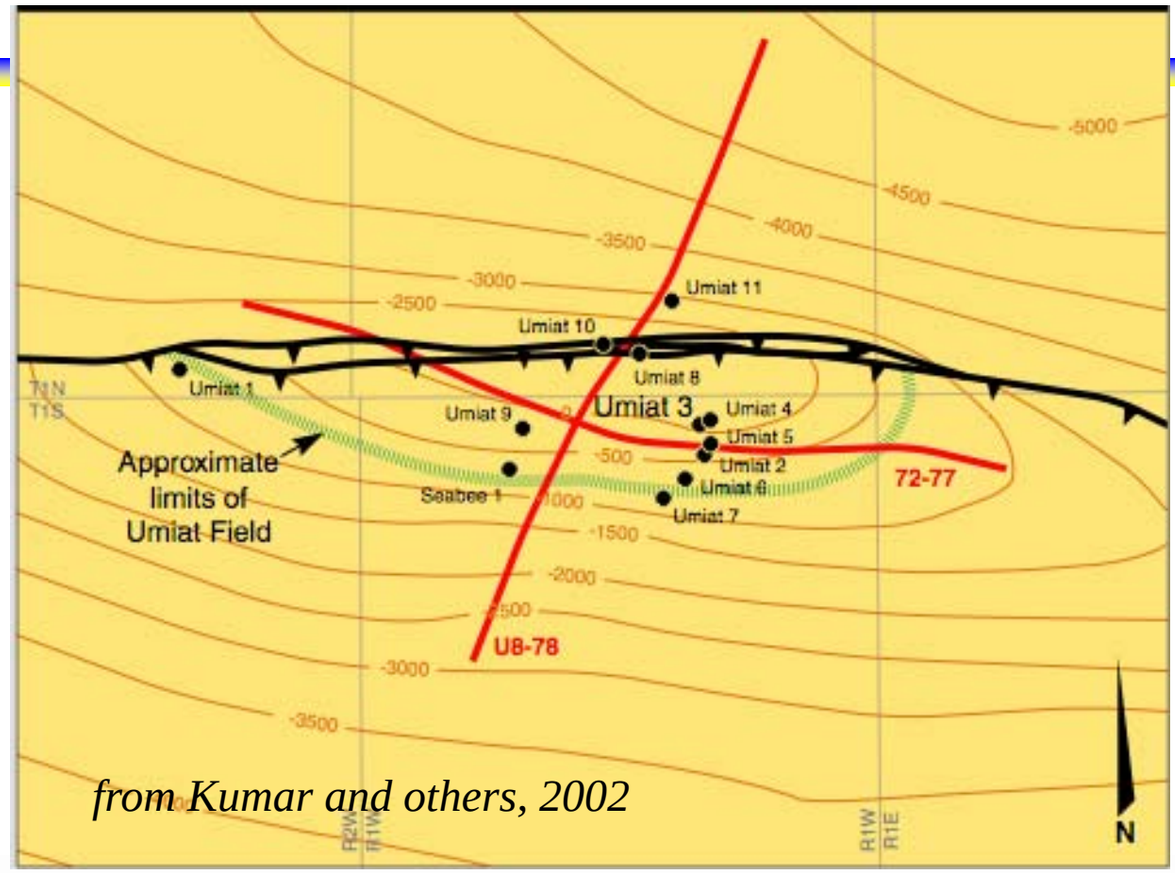
Trap type: Thrust-related anticline

Reservoir: Cretaceous Nanushuk Gp.

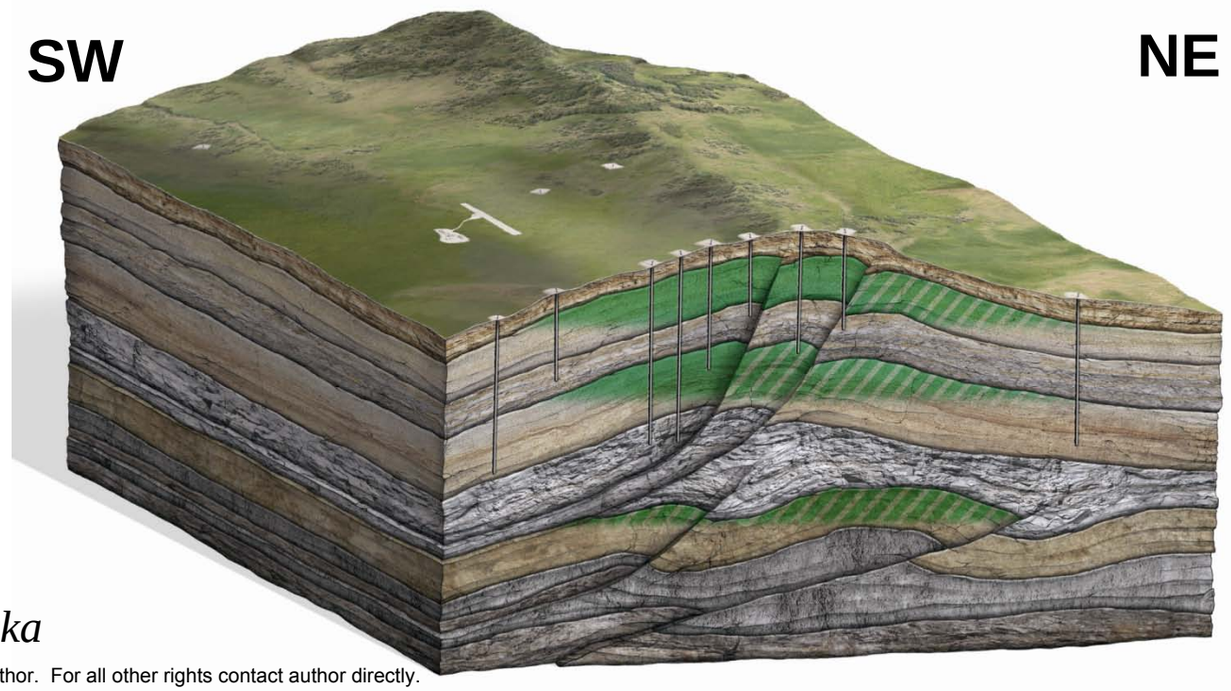
Depth to reservoir: 275-1055 feet

Published estimated reserves: 70 MMBO, 50 BCFG

New estimates: potentially > 1 Billion barrels OOIP



from Kumar and others, 2002



structural interpretation courtesy of Renaissance Alaska

How is Umiat unconventional?

The reservoir is shallow (275-1100 ft) and located in the permafrost.

While modern horizontal drilling techniques could access the reservoir, the presence of ice and low reservoir pressures are a major source of uncertainty:

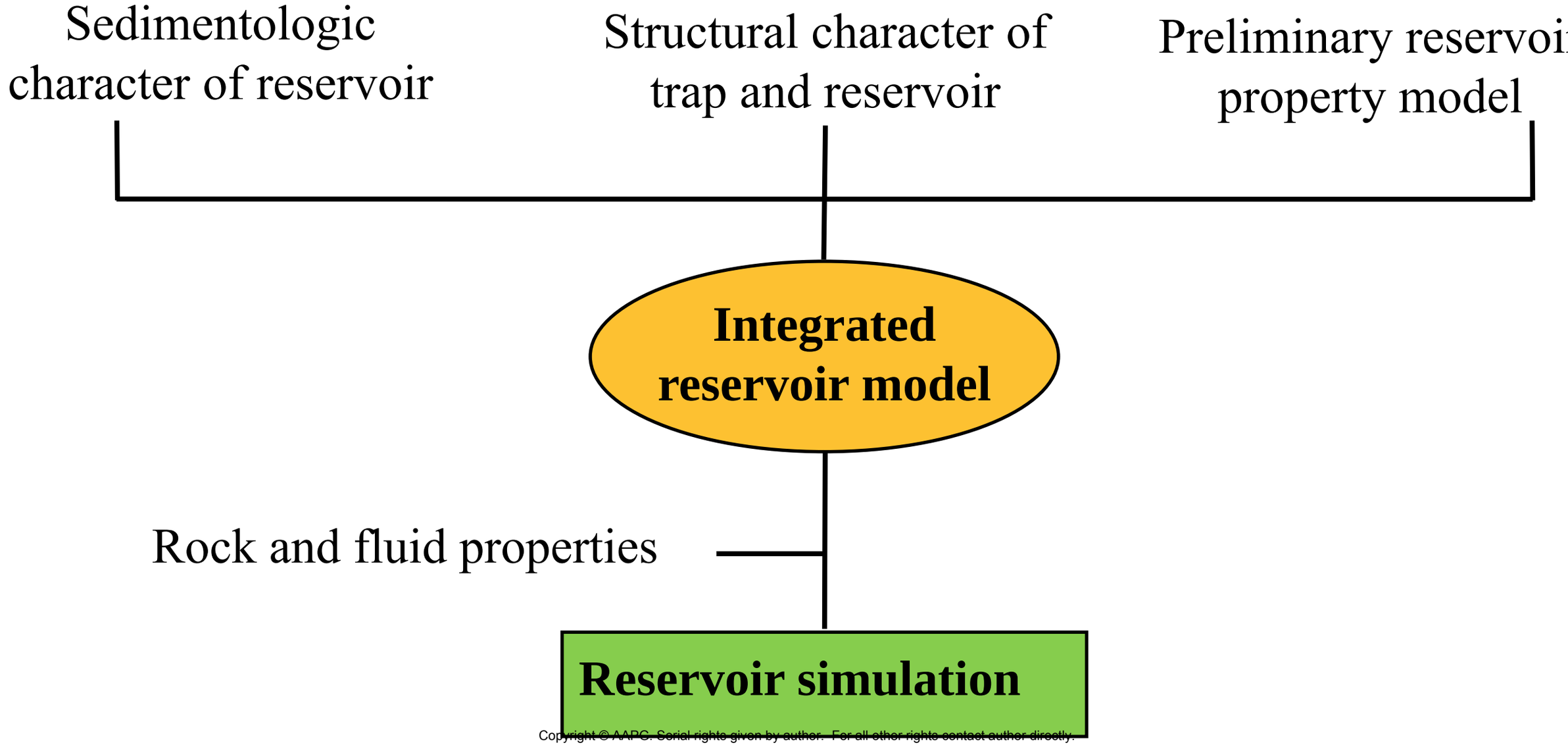
•How might the geologic character of the reservoir influence its productivity under these conditions?

•How does a gas/oil/water system behave in the presence of frozen bound water; i.e., ice around the sand grains?

Image downloadable for presentations at: http://maps.grida.no/go/graphic/permafrost-distribution-in-the-arctic

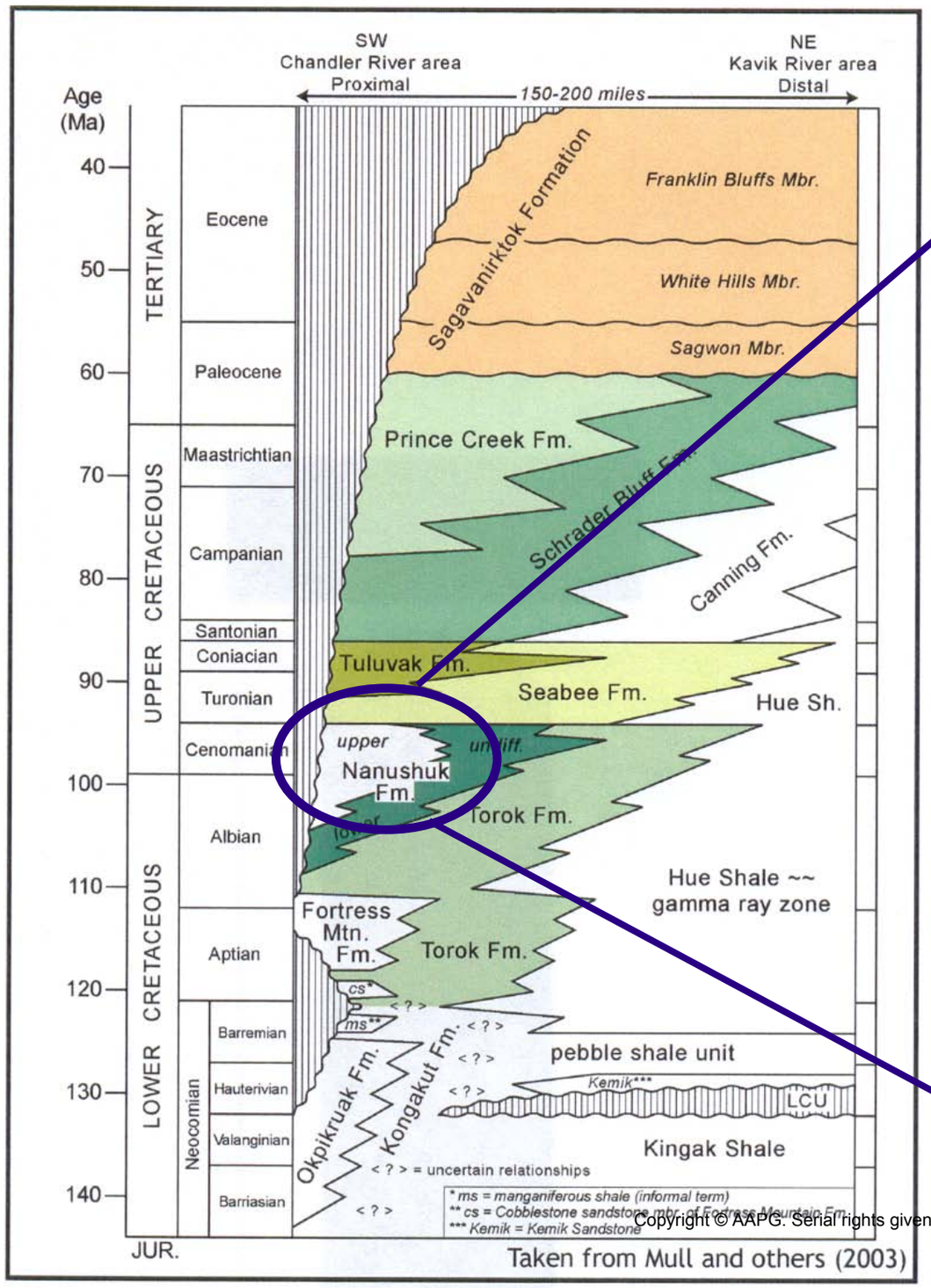
Project approach

Goal: Develop a robust geologic model of the reservoir that can then be used to evaluate different development and production strategies.



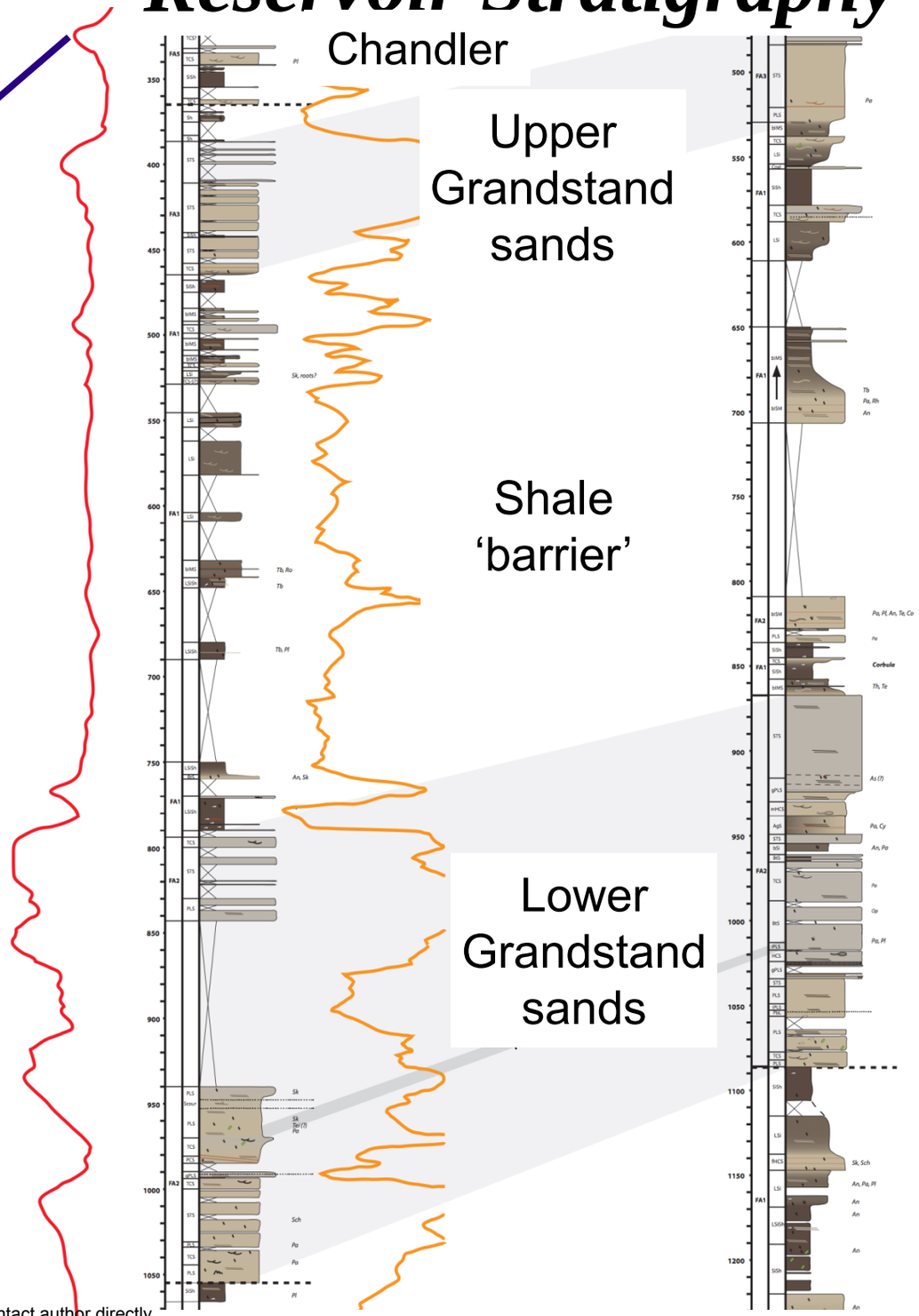
Sedimentologic model

Regional Stratigraphy



Taken from Mull and others (2003)

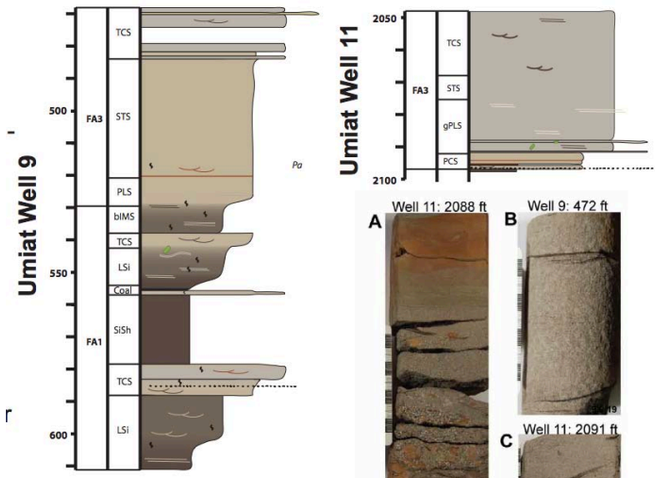
Reservoir Stratigraphy



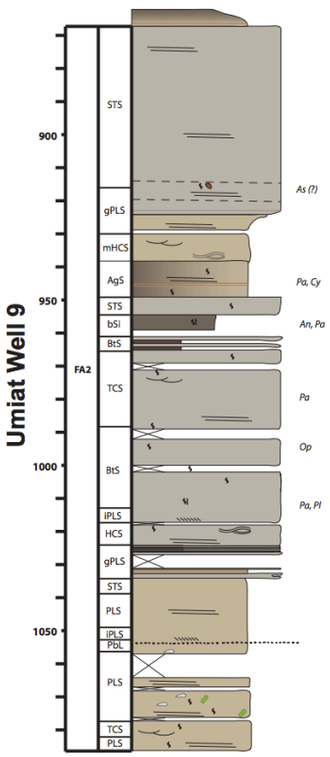
Sedimentologic model

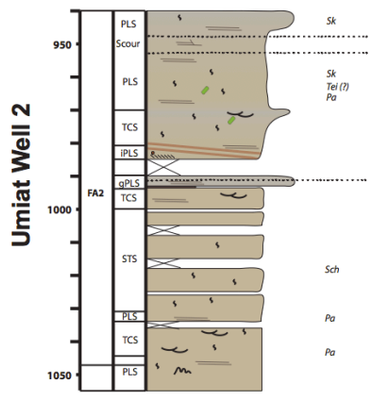
Preliminary results indicate that the Umiat reservoir sands are a storm-influenced deltaic system

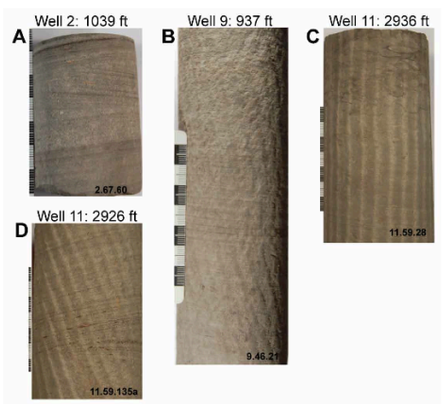
Distributary channel mouth bar



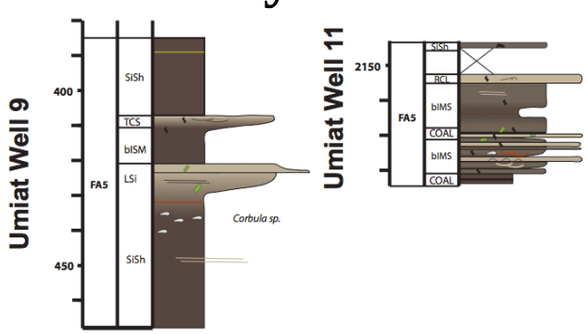
Storm-influenced shoreface

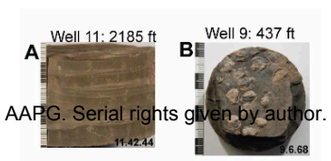


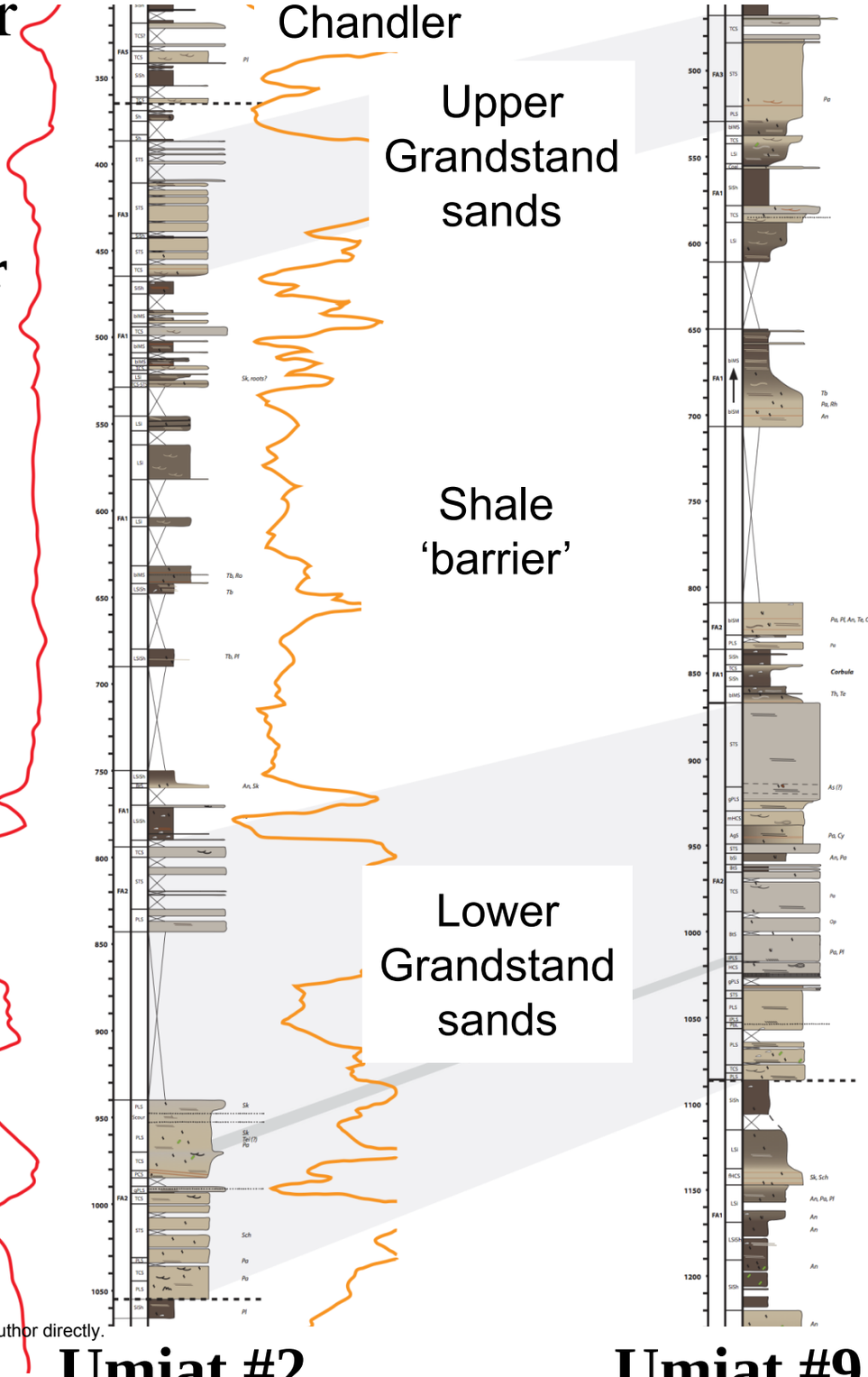




Bay fill





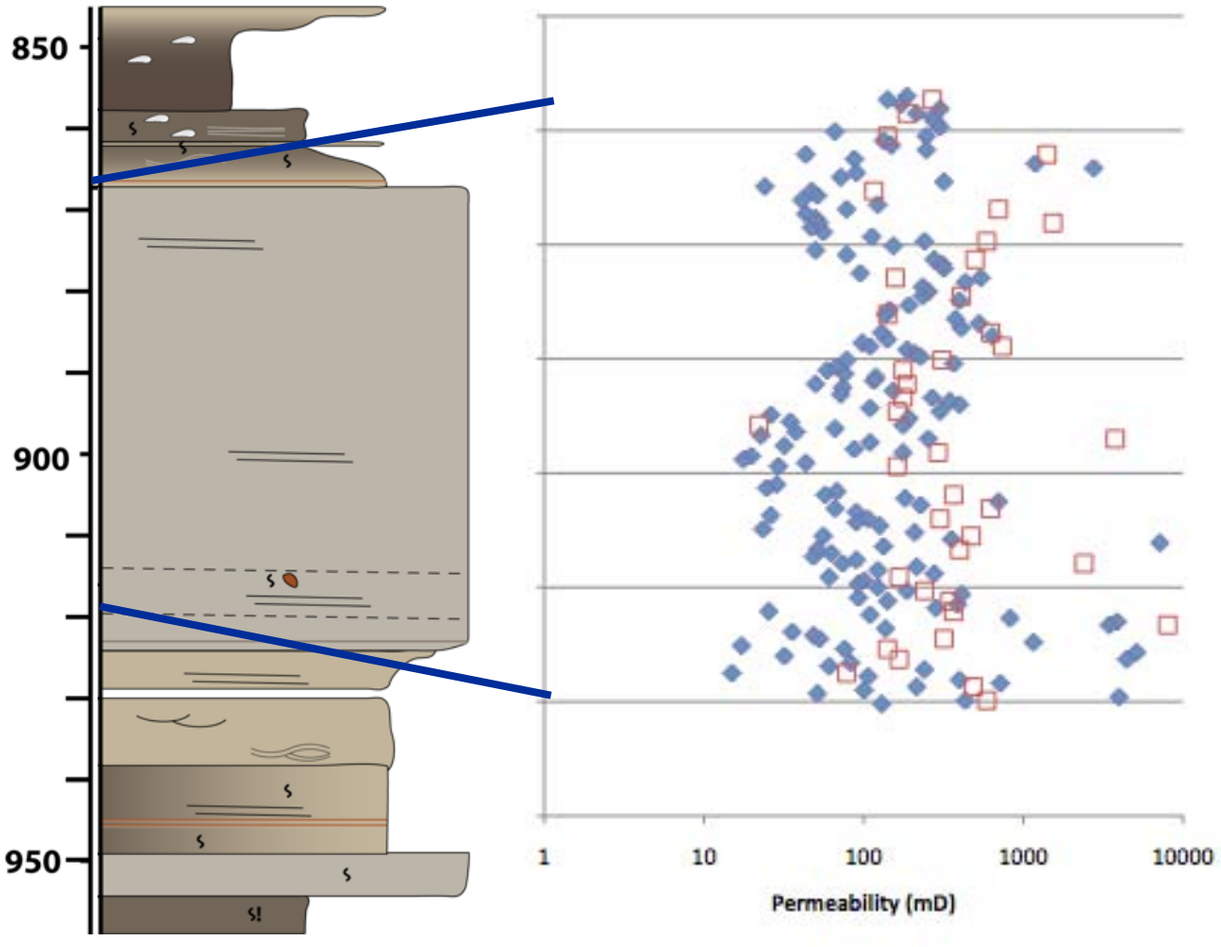


Sedimentologic model

Different facies show different permeability structures

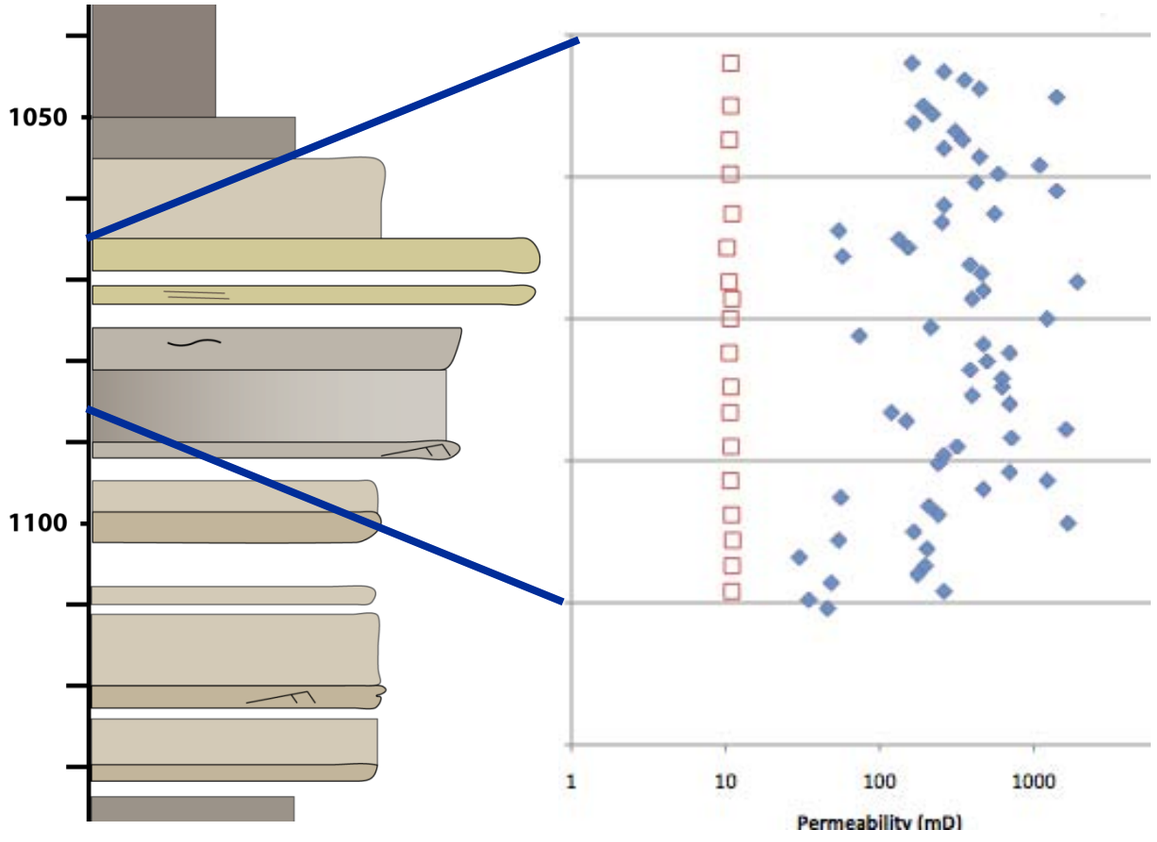
Umiat #9

Kv/Kh ≥ 1



Umiat # 10

Kv/Kh <<1

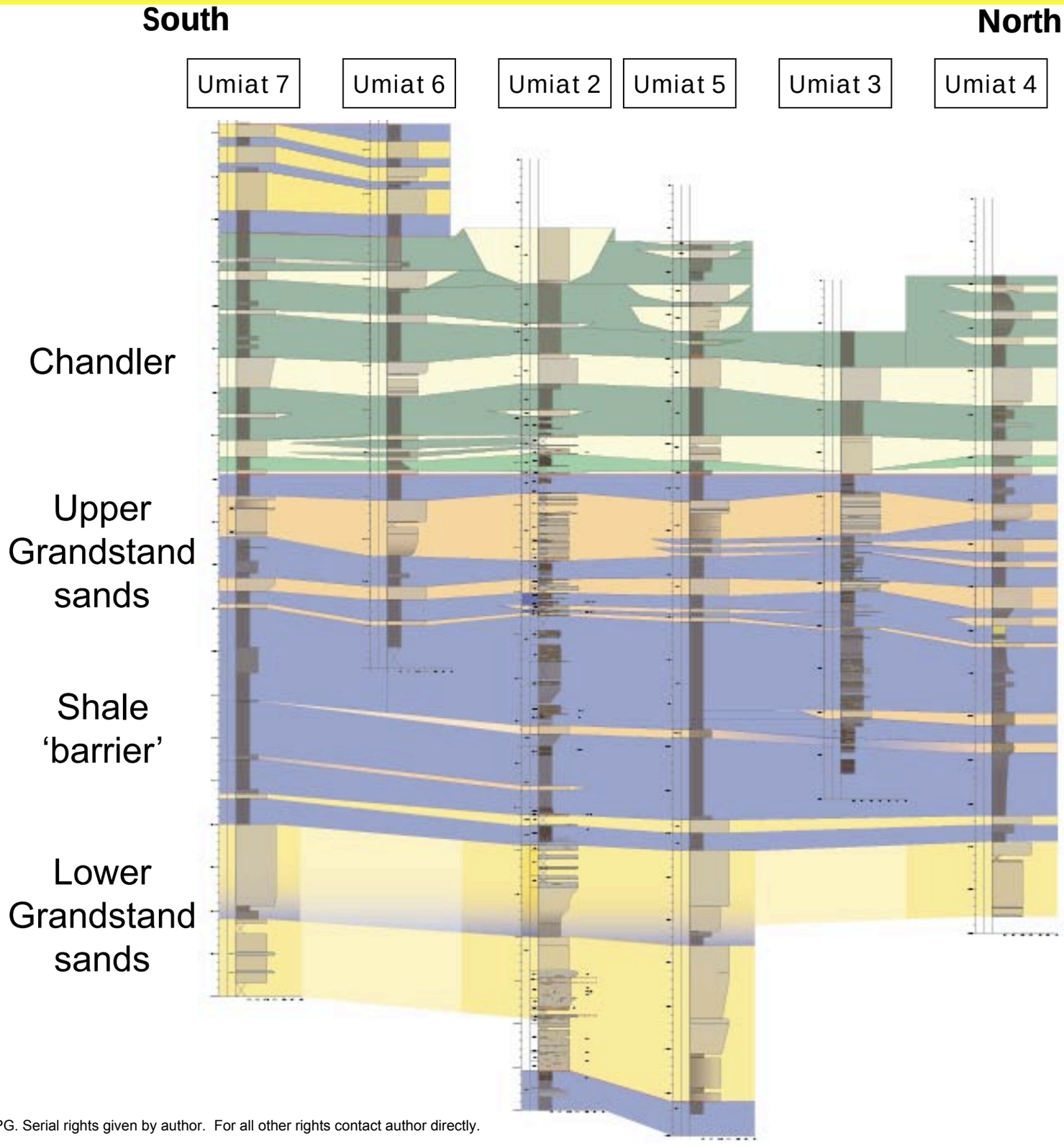


Shoreface sands are bioturbated with only a few preserved sedimentary structures

Distributary channel mouth bar sands are coarser grained, laminated with occasional ripple laminations and cross bedding

Sedimentologic model

Correlation of facies across the field suggest that the permeability structure will vary considerably both laterally and with depth



Color Key

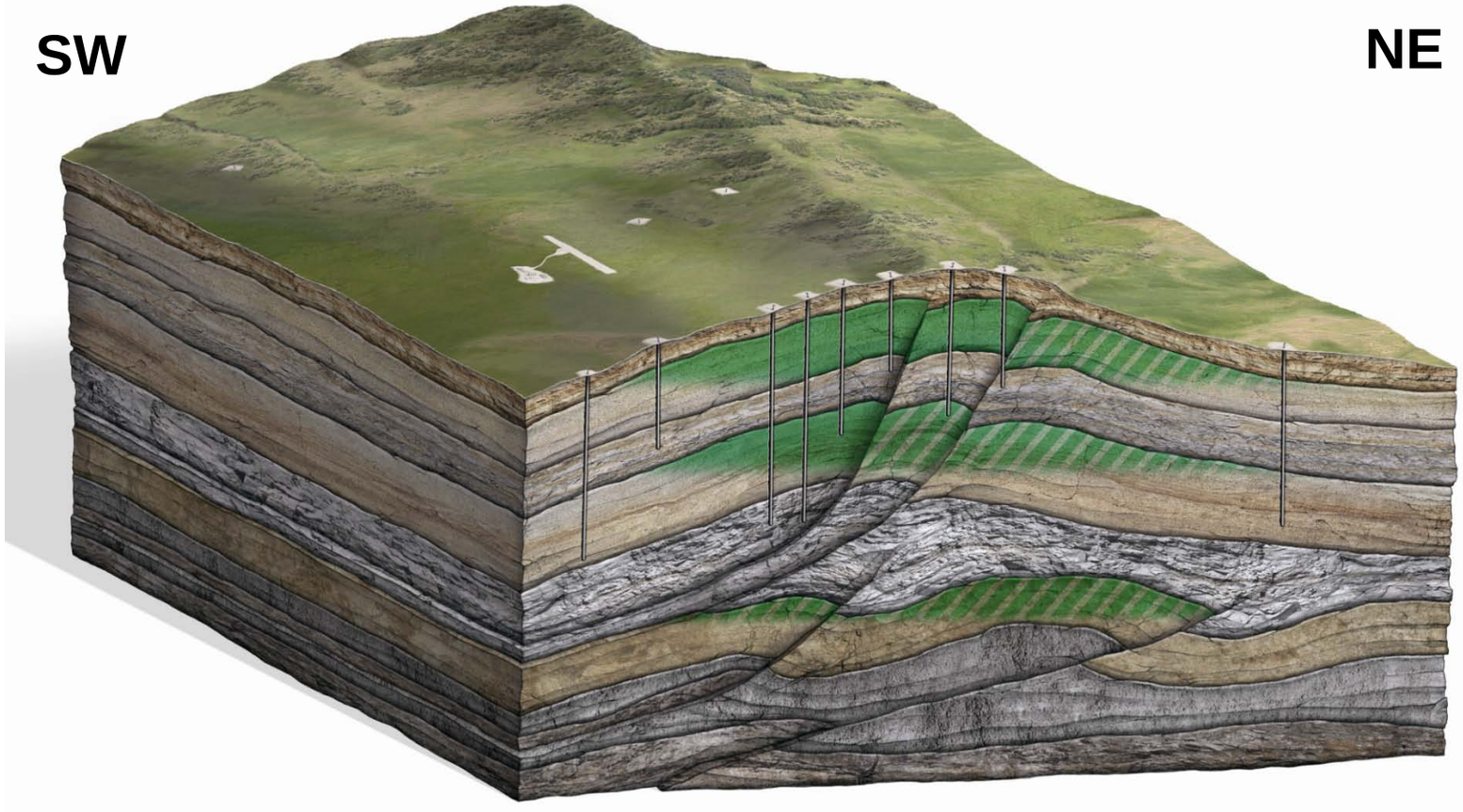
- FA 1: Offshore
- FA 2: Shoreface
- FA 3: Distributary Mouth Bar
- FA 4: Distributary Channel
- FA 5: Bay fill/Estuarine
- FA 6: Delta Plain
- FA 7: Fluvial Channel

Structural model

The Umiat structure is a ESE trending, thrust-related anticline related to a detachment in the underlying shale.

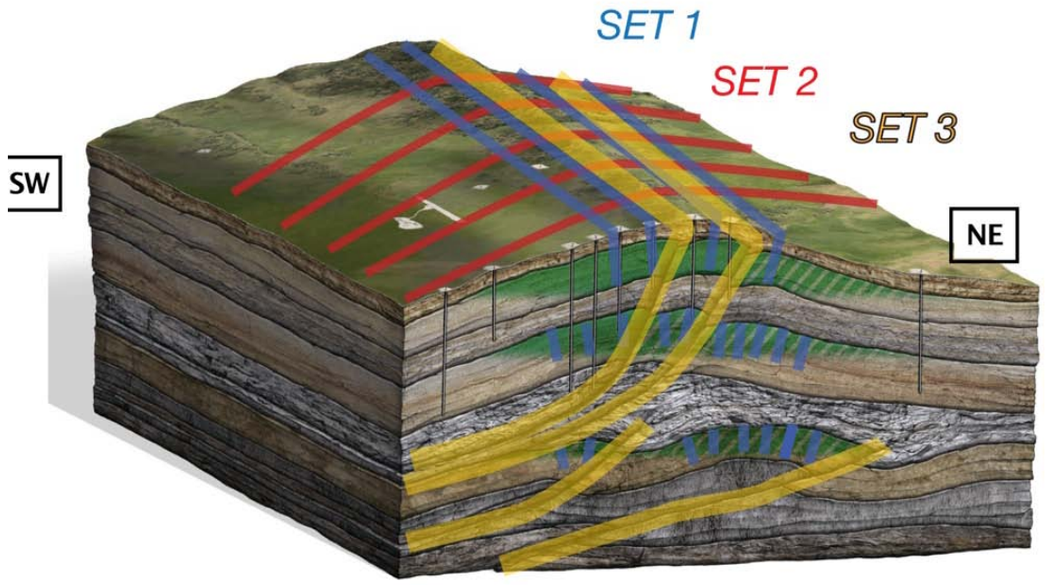
Deeper reservoirs below the shale have different geometries and may be a good target for gas.

Fractures may enhance permeability if open or block permeability if filled with ice or cement.

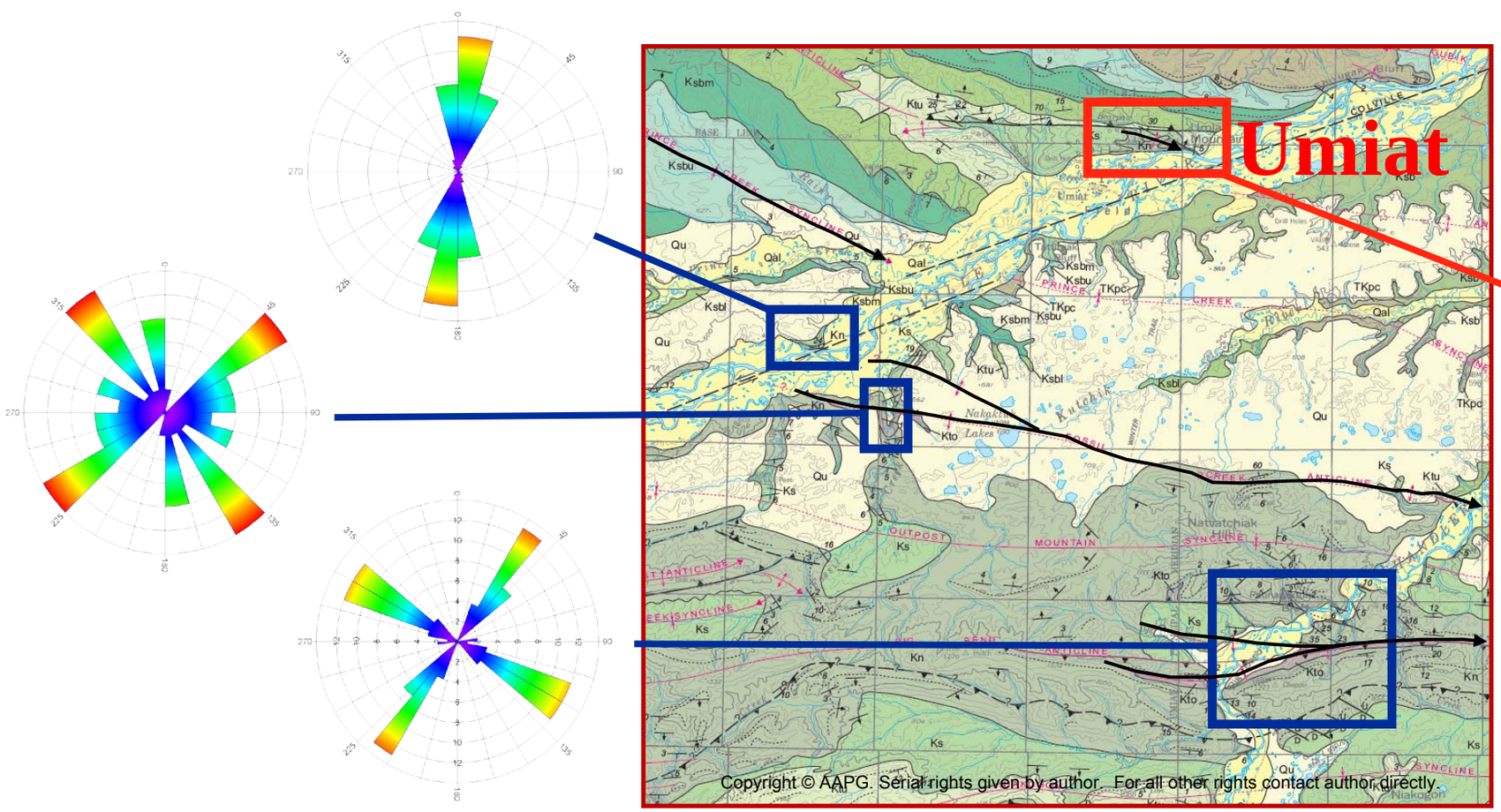


Structural model

Regional and local observations suggest that 3 sets of fractures are likely to occur at Umiat.



2 sets are observed in outcrop.

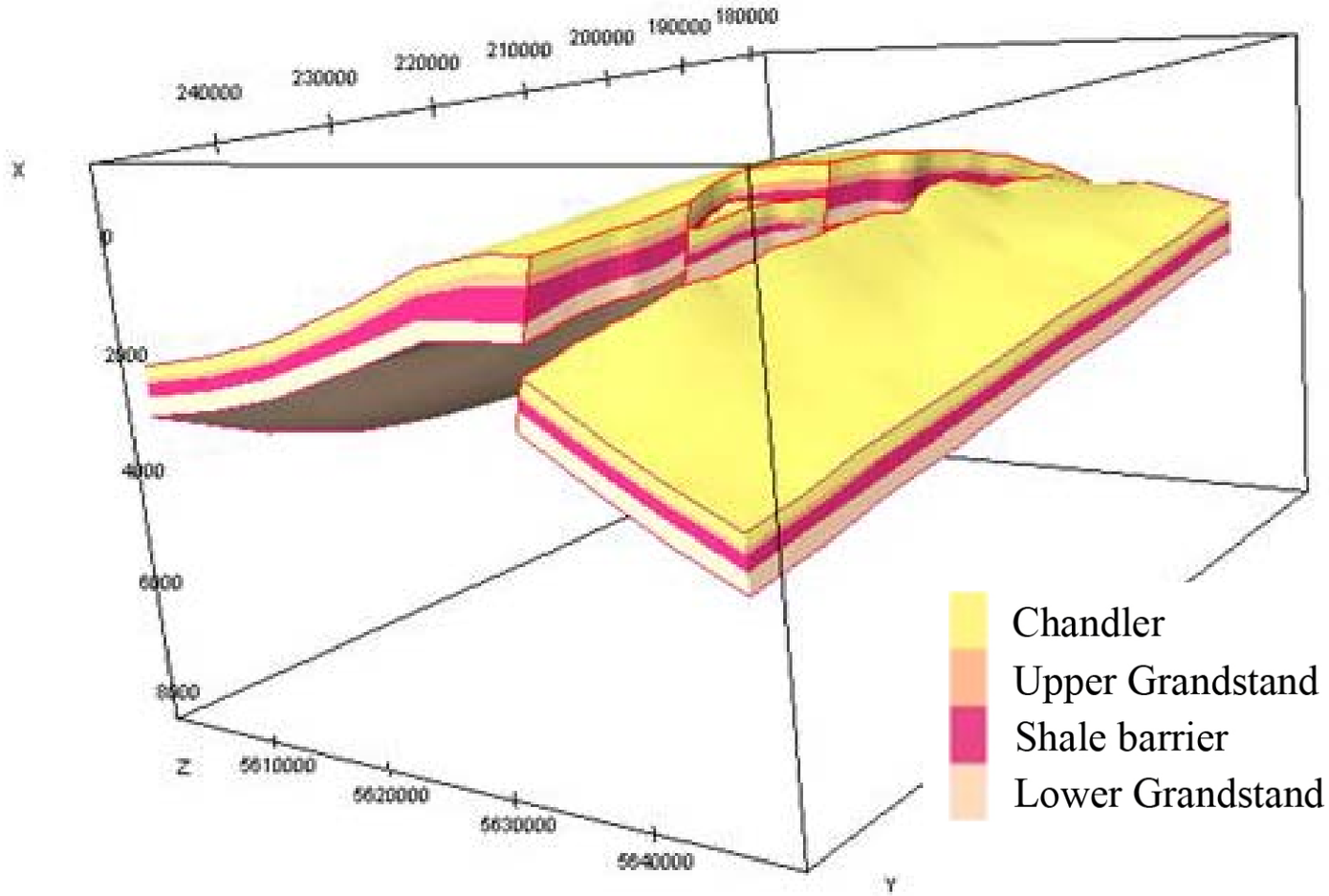


At least 1 set is observed in core

Umiat reservoir model

Statistical analysis of existing petrophysical data and geologic data indicates that the major reservoir intervals have distinct petrophysical properties and flow structures and should be treated separately.

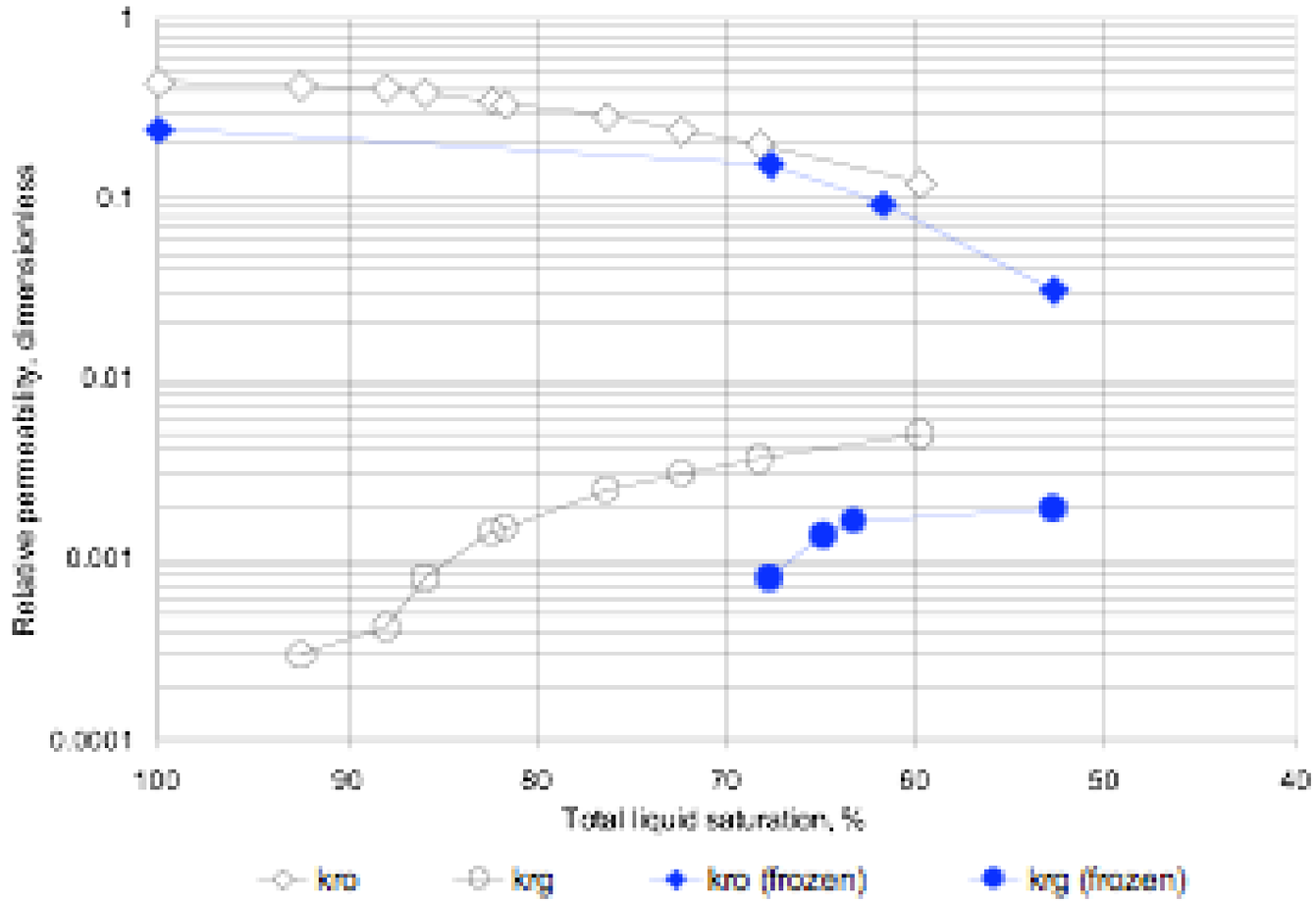
A property model of Umiat field using existing data yields an estimated OOIP is ~ 1.2 billion barrels and 84 bcf associated gas



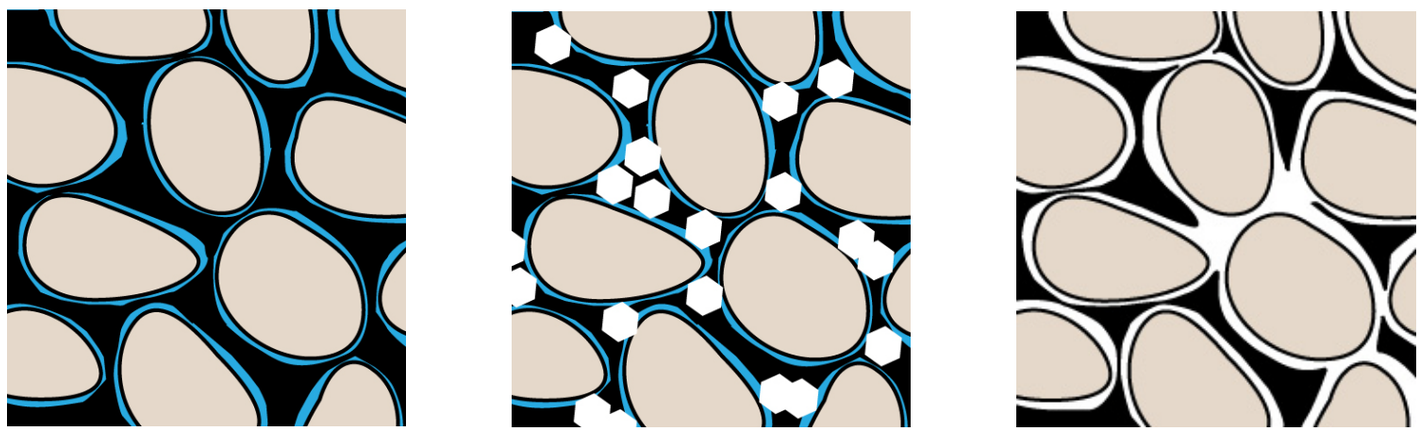
Rock and fluid properties

Experimentally, there is a significant reduction of oil relative permeability at irreducible water saturations in frozen cores when fresh water is used.

However, this reduction in relative permeability is less in cores with saline water, suggesting that saline formation water may inhibit total blockage of pore throats by ice.



This may result in the reservoir productivity being very sensitive to temperature and formation water salinity as well as porosity and permeability distribution.

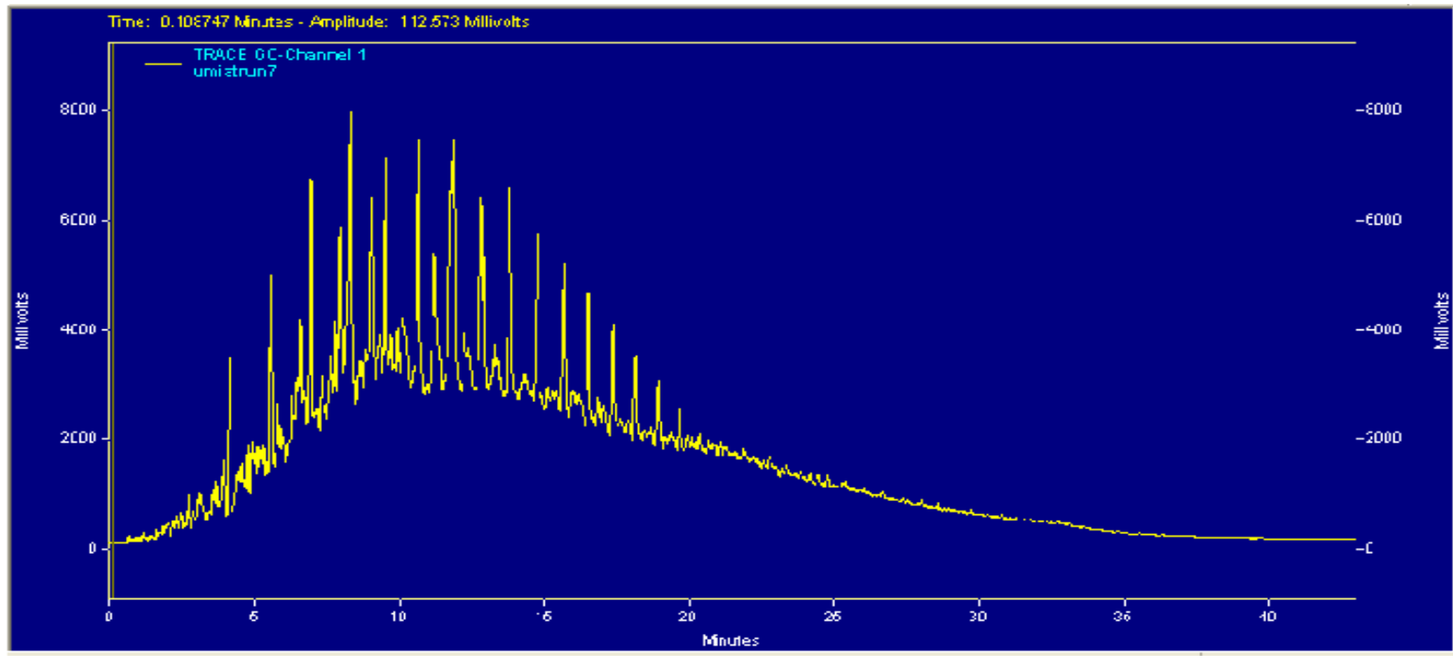


Rock and fluid properties

The available sample Umiat oil has significantly degraded since sampling, with the loss of light ends.

A recombined Umiat sample can be formulated using these compositional analyses. The recombined sample can then be used for phase behavior studies to determine the bubble point and the formation volume factor.

Properties	From Experiments	From Literature (well 8)
°API/Density @ 60°F/0 psig	29.7 °API / 0.8778 gm/cm³	36.6 °API / 0.8432 gm/cm³
	Medium Oil	Light Oil
Viscosity (cp)	9.16	2.5
Molecular Weight (lb/lb-mole)	245	-



Next steps

Complete analysis of sedimentology, diagenesis and permeability distribution

Detailed structural geometry and characterization of fractures

Preliminary reservoir property model

Integrated reservoir model

PVT analysis, additional relative K and NMR studies

Reservoir simulation

Cold gas injection has been identified as a potential production technique

Conclusions

•Umiat field has an estimated OOIP ~ 1.2 billion barrels and 84 bcf associated gas.

•However, the recovery factor will be heavily impacted by low relative permeability of oil. Relative permeability is significantly reduced in the presence of ice, but this effect is not as severe if the connate water is even slightly saline.

•The reservoir at Umiat consists of shoreface sands and associated delta front deposits with significant lateral and vertical variations in porosity and permeability.

•Fractures are present but their effect on permeability has yet to be determined.

•Horizontal drilling and cold gas injection have been identified as probably the most effective potential production mechanism.

Any Questions?

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