Lecture 8

Estimating Ultimate Recovery (EUR)

Outline

- Overview
- Gross Rock Volume
- Reservoir Volume
- Pore Volume
- HC Volume

Reservoir Quality - Overview

- Our ultimate goal is to know how much hydrocarbon (HC) is in the reservoir and what portion we can produce, the estimated ultimate recovery (EUR)
- Our focus is on the amount of HC in place
- It is beyond the scope of this course to estimate the portion that can be produced (typically about 15 to 45% for oil; can be higher for gas)

So how do we get HC in place?

Obtaining HC in Place

- We start by estimating the total volume of rock
- Then we reduce the volume step-by-step until we get an estimate of the volume of HC in the reservoir – gas in the case of Barracouta
**Total Rock Volume**

To get a first approximation, we:
- Map the areal extent of the trap (planimeter)
- Estimate how far down dip the HCs extend
- Convert the isochron map (ms) to an isochore map (m or ft) using velocity data
- Combine the HC extent and the thickness to get a total rock volume (km$^3$ or acre/ft)

**Reservoir Rock Volume**

To get a first approximation, we:
- Start with the total rock volume
- Estimate the net-to-gross for the reservoir interval (good sands versus waste rock)
- Net-to-gross often varies by the environments of deposition
  For Barracouta, we will assume:
  - N/G for shoreface = 80%
  - N/G for delta plain = 65%
  - N/G for fluvial = 50%

**Pore Volume**

To get a first approximation, we:
- Start with the reservoir sand volume
- Use a porosity value (percentage of volume that represents the pore space)
  Porosity often varies by the environments of deposition
  - For our field:
    - $\Phi$ for shoreface = 20%
    - $\Phi$ for delta plain = 18%
    - $\Phi$ for fluvial = 16%

**Hydrocarbon Volume**

To get a first approximation, we:
- Start with the net pore volume
- Use a HC saturation value (e.g. 80% HC saturation means 80% of the pore space contains HCs, the other 20% has irreducible water)
  For this field, we will assume a HC saturation of 90%
We need a recovery efficiency to go from HC in place to recoverable HC.

We will assume a 70% recovery efficiency.

Many factors go into the recovery efficiency, in particular, how effective the reservoir’s “plumbing” is, which is related to permeability.

There is also a volumetric expansion due to the drop in temperature & pressure.
Maturing a Prospect

1. Defining prospect elements
2. Estimating trapped HC volumes
   3. HC Type
   4. Assessment
   5. Risk

Type of HC: Oil or Gas?
- From our basin modeling & HC systems analysis, which fluid type should we expect
  - What did the source generate?
  - What did the trap leak or spill?
- Should there be a difference in seismic response (AVO) between an oil-filled reservoir and a gas-filled reservoir?
  - Model response for different rock & fluid properties
- If there should be a difference, which fluid type does the seismic data support?
  - Extract amplitudes from near- and far-angle stacks

Qualitative Analysis
- We model and compare the volume of oil and gas generated within the fetch area of a trap with trap volume
- We analyze:
  - How might the trap been filled with oil?
  - How might the trap been filled with gas?
  - Have some HCs been spilling out of the trap?
  - Where might spilled HCs end up?
Let's consider a drop of oil generated in the source interval and its journey to a trap. A drop of oil moves up to a carrier bed and its journey to a trap.

For basin modeling, we look for regionally mappable sequences that are (or we believe would be) able to handle secondary migration. We generate depth (or time) structure maps for the tops of these sequences. Then we perform a secondary migration drainage analysis.

Schematic of the surface of a carrier bed showing flow vectors (black arrows), drainage divides (blue lines) and the free gas caps and oil legs of four culminations.

- Use the seismic data to increase our confidence that HCs are present and, perhaps, how much HC volume is present in the trap
- We look for and use DHIs – Direct Hydrocarbon Indicators
- Seismic DHIs are anomalous seismic responses that are caused by the presence of hydrocarbons
- DHIs occur when a change in pore fluids causes a change in the elastic properties of the bulk rock which is seismically detectable (i.e. there is a "fluid effect")
- DHIs display one or more types of characteristics that are consistent with hydrocarbons filling pores in a rock matrix
DHI Characteristics

- **Hydrocarbon Indicators**
  - Amplitude Strength
  - Impedance Signature
  - AVO Response
  - Evidence of Fluid Contact
    - Flat Spot
    - Polarity Reversal
    - Abrupt Down-Dip Termination
    - Fit-to-Structure

- **Other Indicators**
  - Chimneys
  - Sag/Pull-Up
  - Attenuation/Frequency

Impedance Signature

- **Hydrocarbon Indicators**
  - Amplitude Strength
  - Impedance Signature
  - AVO Response
  - Evidence of Fluid Contact
    - Flat Spot
    - Polarity Reversal
    - Abrupt Down-Dip Termination
    - Fit-to-Structure

- **Other Indicators**
  - Chimneys
  - Sag/Pull-Up
  - Attenuation/Frequency

AVO Response

- **Hydrocarbon Indicators**
  - Amplitude Strength
  - Impedance Signature
  - AVO Response
  - Evidence of Fluid Contact
    - Flat Spot
    - Polarity Reversal
    - Abrupt Down-Dip Termination
    - Fit-to-Structure

- **Other Indicators**
  - Chimneys
  - Sag/Pull-Up
  - Attenuation/Frequency

Flat Spot

- **Hydrocarbon Indicators**
  - A change from a lighter to a denser fluid results in a reflector

- **Other Indicators**
  - Chimneys
  - Sag/Pull-Up
  - Attenuation/Frequency

A fluid contact will be flat in depth; it may not be perfectly flat in time

Polarity Reversal

- Hydrocarbon Indicators
  - Amplitude Strength
  - Impedance Signature
  - AVO Response
  - Evidence of Fluid Contact
    - Flat Spot
    - Polarity Reversal
    - Abrupt Down-Dip Termination
    - Fit-to-Structure
- Other Indicators
  - Chimneys
  - Sag/Pull-Up
  - Attenuation/Frequency

Alistair Brown, 2010
Search and Discovery #40514

Reservoir with HC is low impedance; with brine is high impedance

A list of hydrocarbon indicators:
- Amplitude Strength
- Impedance Signature
- AVO Response
- Evidence of Fluid Contact
  - Flat Spot
  - Polarity Reversal
  - Abrupt Down-Dip Termination
  - Fit-to-Structure
- Other Indicators
  - Chimneys
  - Sag/Pull-Up
  - Attenuation/Frequency

Abrupt Termination

- Hydrocarbon Indicators
  - Amplitude Strength
  - Impedance Signature
  - AVO Response
  - Evidence of Fluid Contact
    - Flat Spot
    - Polarity Reversal
    - Abrupt Down-Dip Termination
    - Fit-to-Structure
- Other Indicators
  - Chimneys
  - Sag/Pull-Up
  - Attenuation/Frequency

Fit-to-Structure

- Hydrocarbon Indicators
  - Amplitude Strength
  - Impedance Signature
  - AVO Response
  - Evidence of Fluid Contact
    - Flat Spot
    - Polarity Reversal
    - Abrupt Down-Dip Termination
    - Fit-to-Structure
- Other Indicators
  - Chimneys
  - Sag/Pull-Up
  - Attenuation/Frequency

AVO: Quantification

We quantify the AVO response in terms of two (2) parameters:
- Intercept (A) - where the curve intersects 0º
- Slope (B) - a linear fit to the AVO data

For some reservoirs, the AVO response differs when gas, oil and water fill the pore space.
Modeling AVO

Porosity

10% Porosity

20% Porosity

30% Porosity

Gas

Oil

Brine

Modeling Output

Porosity

10% Porosity Offset

20% Porosity Offset

30% Porosity Offset

Model Seismic Responses - Output

AVO Cross Plot

Gas

Oil

Brine

Shale

Simple Prospects

For our discussion, I'll use a hypothetical area with two (2) anticlines: Alpha and Beta

Should we drill Alpha?

Should we drill Beta?
**Most-Likely Scenario**

Map of the Reservoir Unit

- Alpha
- Beta
- Oil

18 Ma

**Most-Likely Scenario**

Map of the Reservoir Unit

- Alpha
- Beta
- Oil

10 Ma

**Questions???

*Our Most-Likely Scenario*

*Many times the seismic data will give us clues!*

- How can we verify this scenario?
- To what level are the traps filled with oil & gas?
- What would be the value ($) if our scenario is correct?
- How much more/less HC could there be?
- How risky is this prospect (chance that we are totally wrong)?
Seismic Line Across ‘Alpha’

Fluid Contact? Gas over Oil?

Fluid Contact? Oil over Water?

Maturing a Prospect

1. Define prospect elements
2. Estimating trap volumes
3. HC Type
4. Assessment
5. Risk

Types of Assessments

Once a lead has been high-graded into a prospect, we have to assess its potential value

- **Deterministic Assessment**
  - One value for each parameter
  - One final number, e.g., 200 MBO

- **Probabilistic Assessment**
  - A range of values for each parameter
  - A range of outcomes, e.g. 200 ± 50 MBO

Deterministic Assessment

For a Deterministic Assessment, we assign numbers to the parameters related to HC volumes

For example, if:
- the reservoir extends over 18.5 km²
- average thickness is 100 m
- the most likely net-to-gross is 35%
- the expected porosity is 28%
- hydrocarbon saturation is 80%
- the formation volume factor is 1.33
- the recovery efficiency is 0.25

\[
\begin{align*}
\text{Gross Rock Volume:} & \quad 1850 \text{ Mm}^3 \text{ or } 11,100 \text{ MB} \\
\text{Oil in Place:} & \quad 960 \text{ MB} \\
\text{Unrisked Recoverable Oil:} & \quad 320 \text{ MB}
\end{align*}
\]

Unrisked means everything in the HC System has worked!
**Scenarios & Probabilities**

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>Alpha</td>
</tr>
<tr>
<td>Gas Cap &amp; Oil Leg</td>
<td>Gas Only</td>
</tr>
<tr>
<td>45% Chance of Occurrence</td>
<td>25% Chance of Occurrence</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>Alpha</td>
</tr>
<tr>
<td>Oil Only</td>
<td>Low Gas Saturation</td>
</tr>
<tr>
<td>20% Chance of Occurrence</td>
<td>10% Chance of Occurrence</td>
</tr>
</tbody>
</table>

**Deterministic Prospect Assessment**

To assess a prospect, we assign numbers to the parameters related to HC volumes.

### For our hypothetical Alpha and Beta

<table>
<thead>
<tr>
<th>ESTIMATES</th>
<th>Alpha</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gross Rock Volume</td>
<td>2.91 km³</td>
<td>2.21 km³</td>
</tr>
<tr>
<td>2. Reservoir Volume</td>
<td>1.02 km³</td>
<td>0.66 km³</td>
</tr>
<tr>
<td>3. Pore Volume</td>
<td>0.255 km³</td>
<td>0.145 km³</td>
</tr>
<tr>
<td>4. In-Place Volume</td>
<td>0.304 km³</td>
<td>0.116 km³</td>
</tr>
<tr>
<td>5. In-Place - Barrels</td>
<td>1.883 MBO</td>
<td>0.730 MBO</td>
</tr>
<tr>
<td>6. EUR</td>
<td>320 MBO</td>
<td>146 MBO</td>
</tr>
<tr>
<td>7. EUR – Barrels</td>
<td>320 MBO</td>
<td>146 MBO</td>
</tr>
</tbody>
</table>

Unrisked means everything in the HC System has worked!

**Alpha Prospect Assessment**

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil &amp; Gas</td>
<td>Oil Only</td>
<td>Oil Only</td>
<td>Low Gas Saturation</td>
</tr>
<tr>
<td>240 MBO</td>
<td>0 MBO</td>
<td>320 MBO</td>
<td>0 MBO</td>
</tr>
<tr>
<td>120 GCF</td>
<td>440 GCF</td>
<td>0 GCF</td>
<td>0 GCF</td>
</tr>
<tr>
<td>260 MOEB</td>
<td>73 MOEB</td>
<td>320 MOEB</td>
<td>0 MOEB</td>
</tr>
</tbody>
</table>

Assuming 100 MOEB is needed to make prospect economic.

**Probabilistic Assessment**

- The Goal is to get a number and a range of possible outcomes.
- We input a range of values for each assessment parameter
  - usually minimum, most-likely, maximum.

### Parameters

- Area
- Thickness
- Net:Gross
- Porosity
- FVF
- Recovery
- HC Sat.
Unrisked Results

We use a Monte Carlo method to come up with 1000 possible outcomes varying each input parameter given their value distributions.

Maturing a Prospect

1. Define prospect elements
2. Estimating trap volumes
3. HC Type
4. Assessment
5. Risk

How Confident Are We?

75% Chance of Success
25% Risk

9 Key Elements of the HC System

Source Quality
Reservoir Presence
Trap Quality
Source Maturation
Reservoir Quality
Seal Adequacy
HC Migration
Biodegradation
Not Low Gas Saturation

• A team of experts consider these key elements for each prospect
• They rate the chance of success (COS) for each on a scale of 0 to 1

COS for Alpha

• Alpha's biggest risk is that the fault does not seal
• There is also a chance that the trap is only filled with low saturation gas

\[
\text{COS} = \begin{cases} 
1 & \text{Reservoir Presence} \\
1 & \text{Reservoir Quality} \\
1 & \text{Trap Quality} \\
0.8 & \text{Seal Adequacy} \\
1 & \text{Source Quality} \\
1 & \text{Source Maturation} \\
1 & \text{HC Migration} \\
0.9 & \text{NOT Low Gas Saturation} \\
1 & \text{NO Biodegradation} 
\end{cases}
\]

\begin{align*}
\text{chance of success (COS)} & = 0.72 \\
\text{Highest Risk} & = 1.0 \\
\text{Some Risk} & = 0.9 \\
\text{Some Risk} & = 1.0 \\
\text{Some Risk} & = 1.0 \\
\text{Some Risk} & = 1.0 \\
\text{Some Risk} & = 1.0 \\
\text{Some Risk} & = 1.0 \\
\text{Some Risk} & = 1.0 \\
\end{align*}
Risked Probabilistic Assessment Results

Alpha Prospect – Risked

- 72% Chance to find some hydrocarbons
- 58% Chance to find 100 MBOE
- 5% Chance to find 400 MBOE

72% Chance to find some hydrocarbons
58% Chance to find 100 MBOE
5% Chance to find 400 MBOE

North Sea Example

An Example Drainage Polygon:

- Has a unique ID number (e.g., 12345).
- Has a trap defined by a culmination depth and a spill/leak depth.
- Has local HC generation (fetch volume).
- Has spillage into it from a deeper drainage polygon.
- Trap pore volume is filled with oil and gas:
  - Filled with oil + dissolved gas.
  - If excess gas, a gas cap is formed.
  - If there is too much gas, oil (with dissolved gas) spills first.
  - If all the oil spills and there is still excess gas, then gas will spill.

HC Drainage

Local Drainage:

- HC generation
- HC expulsion
- Primary migration
- Secondary migration to local structural culmination
  - Paleo-structure of the top of carrier
  - Along the steepest gradient
- HC loss during migration
Drainage and Spillage

HC Spillage:
- HC charge to trap
  - Previously stored
  - Incremental drainage
  - Spill into drainage
- Gas volumetrics
  - In-situ gas density
  - Gas in solution
  - Gas leakage through cap
- Spillage out of trap
  - Excess volume
  - Spill direction
  - Oil flushed by gas

Modeled Trap HC Fill

Oil Fill:
- Starts about 90 MYA
- Last Oil about 20 MYA
- Oil spill is occurring

Total Gas Fill:
- Starts about 90 MYA
- Increase until 70 MYA
- Some leak at the top
- Max gas generation starts 30 MYA
- Gas flushed out oil

Free Gas Fill:
- Starts about 90 MYA
- Increase until 70 MYA
- Some gas dissolved in oil until 25 MYA
- Much more gas than can be dissolved in decreasing oil volume
Lecture 10

Management Review

NOTE: These materials are for educational purposes for undergraduate and graduate students ONLY. If you are not a student or faculty member, please do not use these resources.

WARNING

Should you be preparing for an IBA competition, please note:
- I have guided you through a few typical analysis steps, not a complete analysis
- Each IBA data set is different with different amounts of well and seismic data, so the analysis of each data set would be different
- Don’t force your data set and objectives into my example
- You want to use creativity in all that you do
- Do NOT expect to mimic this example and win a prize!

Your Objective

What is the ultimate goal for on-the-job technical reporting – written or oral?

To Convey information that results in Action

What is Your Main Message?

- You want the tone, brevity and information transfer that you have in a normal conversation
- Try this:
  - Image you are on the phone with your main reader
  - She is about to go into a meeting with the VP
  - She called you for the latest … “about that problem we discussed last week, quickly fill me in before I have to go in and speak to the VP in about 3 minutes
An Informative Outline

Answer five main questions, keeping your primary reader in mind
1. What is my news? – my headlines
2. Why is this important? – the significance to the reader or the company as a whole – cheaper, better, faster. This news could be positive, negative, or to be determined
3. How do you know? – a terse review of the foundational information behind your news, the essentials of your supporting information
4. Now what? – what action should be taken, what is the next step or steps?
5. How much detail should I include in an appendix or back up slides?

Good Business Report

Front-loaded with the News
"NEWS"

What?
Why?
How?
Now what?

Informative Style

Appendix: Technical details

Suggestions

- Plan your report (presentation) EARLY
- Use the Informative Outline
- Keep notes about observations and thoughts
- Capture images and texts as you go in a work PPT; it's easier to cut than recreate
- Work on essentials; don't lose too much time on what you don't need

Topics for an IBA Report

- Not every topic may be appropriate for your data set and recommendations
- Keep in mind your very limited presentation time

An economic analysis is not expected and should not be conducted.
**The Tiger Report**

**Our NEWS**
- We will propose a wildcat location on a huge anticline with a mean risked reserve of 1.6 TCF and a 70% chance of exceeding the economic minimum of 1.0 TCF

**NOTICE:**
- News is up front
- Call for action
- Packed with info
- Bottom line numbers
- Grabs attention

**The Tiger Report**

**Importance**
- First well offshore Antarctica
- This well could open up a new HC province
- We present a gas-only case; there is a reasonable chance for gas with significant oil volumes
- The well will test a huge anticline AND a play concept with upside potential for the basin

**The Tiger Report**

**How do we know**
- Location
- Available data
- Play element analysis
- Prospect definition
- Volumetric estimates
- Chance of success determination

**The Tiger Report**

**Now what?**
- Proposed wildcat well location
- Cost estimates
- Profit analysis ❄ Not part of IBA ❄
- We are seeking your approval to proceed
The Tiger Report

Details
• Oral
  – A series of backup slides
• Written
  – Appendix A
  – Appendix B
  – Appendix C
  – Appendix D

What Follows...
• I will show my presentation as if this was my project area
• I will not give the presentation – I have discussed most of the materials already
• This is more like a running commentary on what I would include
• Note that I have 23 slides, which might still have to be compressed

Tiger Wildcat Proposal

We propose drilling a well in the Ross Basin, Offshore Antarctica

Risked
70% Chance to have 1.0 TCF or more
68% Chance to have 1.2 TCF or more
50% Chance to have 1.6 TCF or more
10% Chance to have 2.3 TCF or more

Ross Evaluation Team
• Chris Jones, Team Lead
• Pat Smith
• Jean White
• Sam Miller
• M. J. Wheeler

Location
• A third of the Ross Basin extends onshore
• There are many outcrops of Cretaceous and Paleogene rocks
• There are a number of onshore wells; one gas field
• There are NO offshore wells
**Available Data**

- 4 outcrops of mid Tertiary strata
- 7 onshore wells penetrating the mid-Tertiary
- One onshore gas field - Penguin
- Sparse offshore grid of 2D seismic data
- One offshore 3D survey

**The Ross Basin**

**Tectonic Summary**
- The basin is an extensional, pull-apart basin
- Rifting started in the Early Cretaceous
- Extension ceased near the end of the Cretaceous

**Onshore Stratigraphic Summary**
- The Neogene has thin, fluvial deposits
- The Oligocene has fluvial to nearshore
- The Eocene is mid slope to shelfal
- The Paleocene has deep water shales
- The Upper K is fluvial to nearshore-offshore

**Geologic History Summary**
- During the Upper K there was a regression followed by a minor marine transgression
- A major unconformity occurred at the end of the Cretaceous
- The area subsided rapidly, which resulted in a major marine transgression
- As subsidence slowed, a new regression occurred
- During the Eocene the basin slowly filled (slope to shelfal)
- The regression continued to the present

**Late Jurassic – Pre-Rifting**

**Hillary Formation**
- Prior to the onset of rifting between East Antarctica and West Antarctica
- Mostly continental sedimentation with minor marine incursions

**Early Cretaceous – Early Rifting**

**Amundsen Formation**
- Rifting commenced in the Ross Sea separating East and West Antarctica
- Early syn-rift sediments including volcanoclastics and major coal seams
- First significant marine incursions
**Upper Cretaceous – Late Rifting**

**Scott Formation**
- Late syn-rift phase clastic sediments
- Declining clastic sediment input
- As rifting ceased in the Ross Basin (~65 MY), the region collapsed rapidly and fault blocks rotated
- A major transgression occurred

**Paleocene – Initial Sag Phase**

**Nansen FM/Shackleton Member**
- Time of a world-class transgression
- Deep marine shales were deposited in the rapidly subsiding basin

**Present Day**

**Larson Formation**
- The major transgression ceased at the end of the Eocene
- A regression occurred during the Oligocene as sedimentation caught up with decreasing subsidence
- Very little deposition from the Miocene to the present

**Stratigraphic Chart**
**Penguin Field**

- 300 BCF gas field
- Upper Scott fluvial reservoir; $\Phi = 12\%$, $k = 300$ mD
- Source is Amundsen coals; Type III, TOC = 35%, HI = 375
- Seal is marine shale of the Shackleton Member

**Seismic Through Field**

Horizons can be correlated from onshore seismic line to offshore 2D line with a small gap

**Play Concept**

- Rotated, extensional fault blocks form large potential structural traps
- The Scott Formation has fluvial and nearshore sands that can have reservoir quality porosity & permeability
- The Shackleton Member can be a very effective seal

- Anticlinal Traps
- Scott Reservoirs
- Shackleton Seals

**Trap**

- Extensional fault blocks associated with Cretaceous rifting
- Later compression enhanced anticlines and fault traps
**Reservoir**

- The Scott Group fluvial to nearshore sandstones are the primary reservoirs.

**Source**

- Coals and coastal plain coaly shales in the Amundsen Fm.
- Dominantly terrestrial plant origin with high total organic carbon (TOC) values.

**Environments of Deposition**

**Oil & Gas Generation Windows**

- Fetch for Tiger
Seal

- Mostly marine shales and marls of the Shackleton Member
- Some shales within the Scott Group act as intra-Scott seals

Maturation & Migration

- The major generation and expulsion was initiated in the Miocene
- Peak generation at depths of 4-5 km for oil and 5-6 km for gas

Proposed Well Location

- Downdip from crest to prove economic minimum for gas only case

Unrisked Reserves

- To be on the conservative side, we will present a gas only case
- Value of the prospect increases significantly if there is oil & gas in the trap

Gas Volumes in BCF

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Most Likely Case</th>
<th>Low-Side Case</th>
<th>High-Side Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recoverable Gas at Surface in Bcf</td>
<td>1600</td>
<td>724</td>
<td>2845</td>
</tr>
</tbody>
</table>

Tiger Prospect - Unrisked

- 97% Chance to have 1.0+ TCF
- 95% Chance to have 1.2+ TCF
- 50% Chance to have 1.7+ TCF
- 10% Chance to have 2.4+ TCF
Risked Reserves

**Risk Factors**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reservoir Presence</td>
<td>0.95</td>
</tr>
<tr>
<td>2. Reservoir Quality</td>
<td>0.95</td>
</tr>
<tr>
<td>3. Trap Quality</td>
<td>1.0</td>
</tr>
<tr>
<td>4. Seal Adequacy</td>
<td>1.0</td>
</tr>
<tr>
<td>5. Source Quality</td>
<td>0.90</td>
</tr>
<tr>
<td>6. Source Maturation</td>
<td>0.95</td>
</tr>
<tr>
<td>7. HC Migration</td>
<td>1.0</td>
</tr>
<tr>
<td>8. Not Low Gas Saturation</td>
<td>0.90</td>
</tr>
<tr>
<td>9. No Biodegradation</td>
<td>0.98</td>
</tr>
<tr>
<td><strong>TOTAL COS</strong></td>
<td><strong>0.72</strong></td>
</tr>
</tbody>
</table>

**Summary & Recommendations**

- The Tiger Prospect is an excellent opportunity to test a play concept in the Ross Basin offshore.
- The play concept has been proven onshore at the Penguin Field (300 BCF).
- There is good evidence for a fluid contact near the crest of the Tiger Anticline.
- Our proposed well location would prove up the economic minimum for a gas only case.
- Our risked most-likely case for gas only is 1.6 TCF, well above the economic minimum of 1 TCF.
- We have a lot of upside potential if there is an oil leg at Tiger (about a 25% chance).

- We seek your approval to drill the Tiger-1 wildcat at a cost of approximately $550 M.

**Questions?**