Lecture 8

Estimating Ultimate Recovery (EUR)

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.

Outline

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

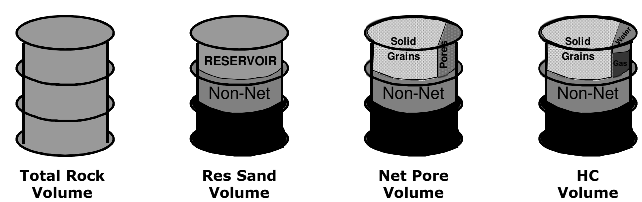
Reservoir Quality - Overview

- 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

AAPG

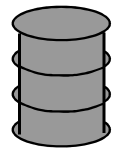
To get a first approximation, we:

– 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)



Total Rock Volume

Field Area
*
Aver. Thickness
↓
Total Rock Vol.

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Reservoir Rock Volume

AAPG

To get a first approximation, we:

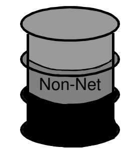
– Start with the total rock volume

– 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%



Res Sand Volume

Total Rx Vol.
*
Net-to-Gross
↓
Res. Rock Vol.

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Pore Volume

AAPG

To get a first approximation, we:

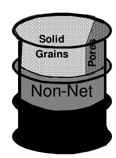
– Start with the reservoir sand volume

– Use a porosity value (percentage of volume that represents the pore space)

Porosity often varies by the environments of deposition

– For our field:

- Φ for shoreface = 20%
- Φ for delta plain = 18%
- Φ for fluvial = 16%



Net Pore Volume

Res. Sand Vol.
*
Porosity
↓
Pore Volume

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Hydrocarbon Volume

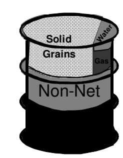
AAPG

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%



HC Volume

Net Pore Vol.
*
HC Saturation
↓
HC Volume

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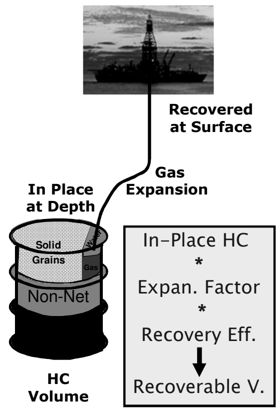
Recoverable HC

- 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



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9

Lecture 9

Maturing a Lead Assessment and Risking

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.

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?

Qualitative

- 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?

Quantitative

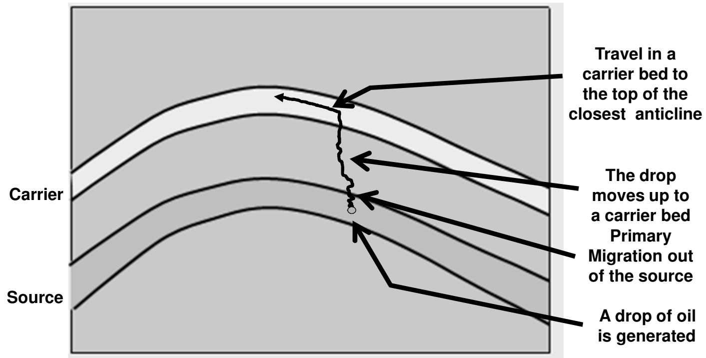
- Should there be a difference in seismic response (AVO) between an oil-filled reservoir and a gas-filled reservoir?
  - Model response for different rock & fluid properties
- If there should be a difference, which fluid type does the seismic data support?
  - Extract amplitudes from near- and far-angle 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?

HC Migration

Let’s consider a drop of oil generated in the source interval and its journey to a trap.



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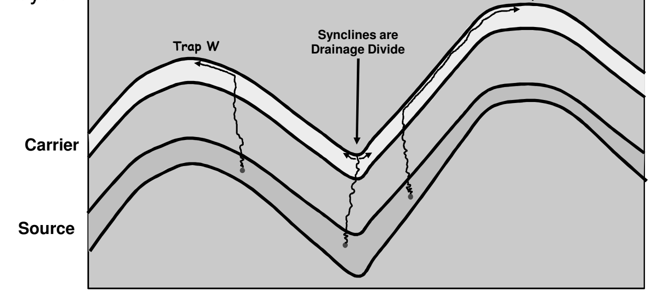
Carrier Bed Migration

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.



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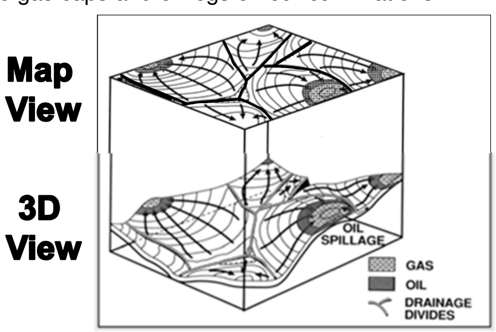
Carrier Bed Modeling

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.



Schroeder & Sylta, 1993

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Quantitative Analysis

- 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

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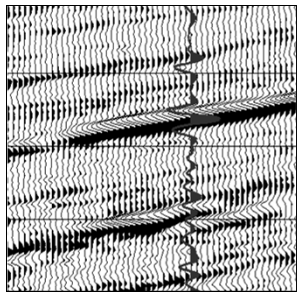
DHI Characteristics

AAPG

- 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

Presence of HCs is marked by high reflection amplitudes



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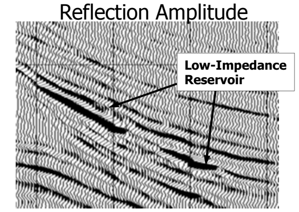
Impedance Signature

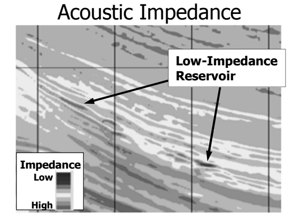
AAPG

- 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

Reflection Amplitude



Acoustic Impedance



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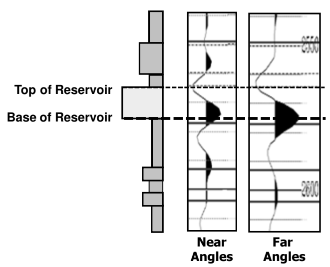
AVO Response

AAPG

- 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

Reflection Amplitude changes as a function of Offset



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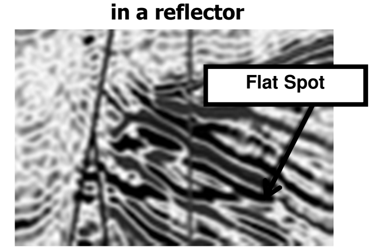
Flat Spot

AAPG

- 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

A change from a lighter to a denser fluid results in a reflector



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

www.geoexpro.com/exploration/westloppa/

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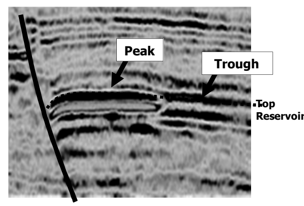
Polarity Reversal

AAPG

- 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

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



Alistair Brown, 2010
Search and Discovery #40514

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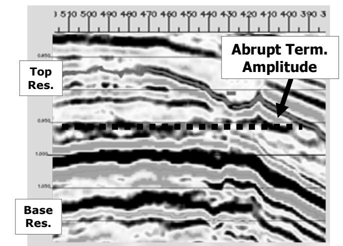
Abrupt Termination

AAPG

- 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

Amplitudes abruptly terminate downdip at a change in fluid contact



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Fit-to-Structure

AAPG

- 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

Amplitude anomaly conforms to a depth (TWT) contour

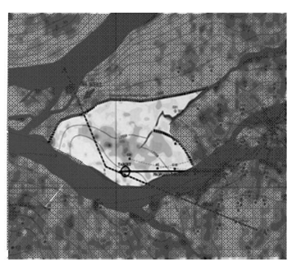

Image courtesy of ExxonMobil

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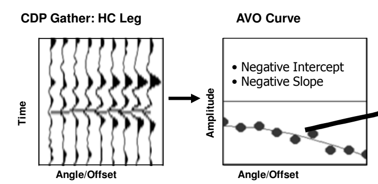
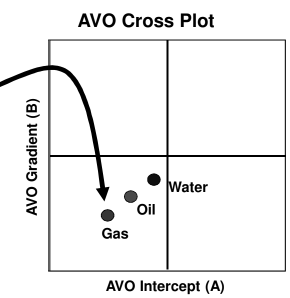
AVO: Quantification

AAPG

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

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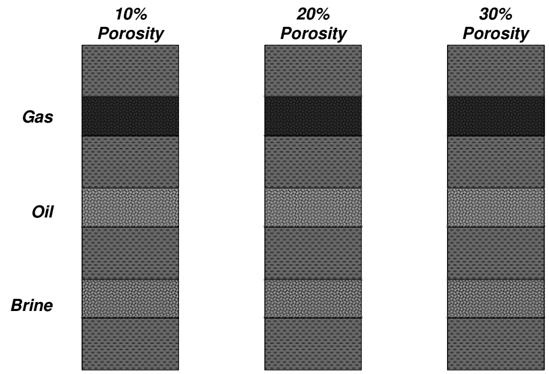
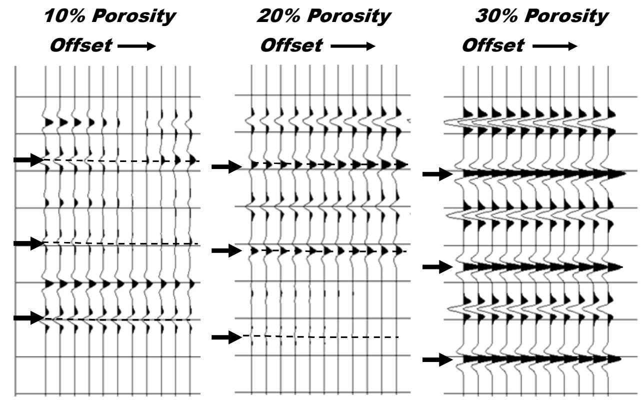
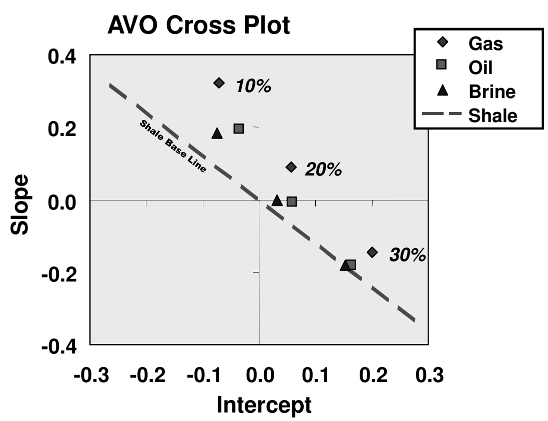
Modeling AVO



Modeling Output



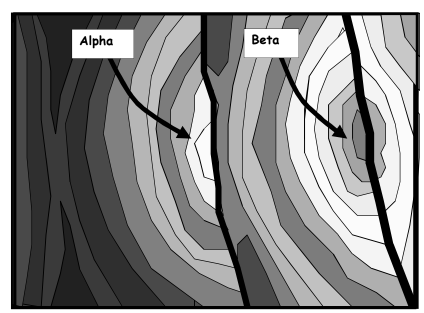
Model Seismic Responses - Output



Simple Prospects

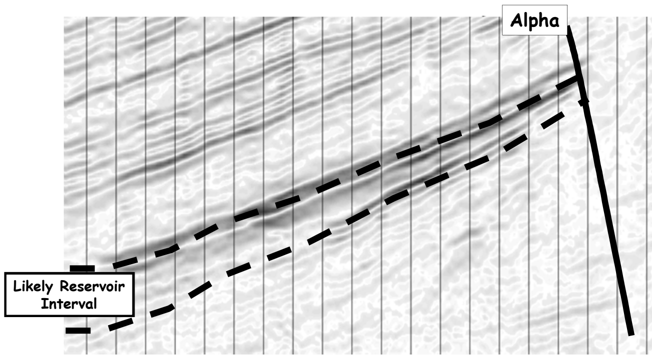
For our discussion, I'll use a hypothetical area with two (2) anticlines: Alpha and Beta

Should we drill Alpha?

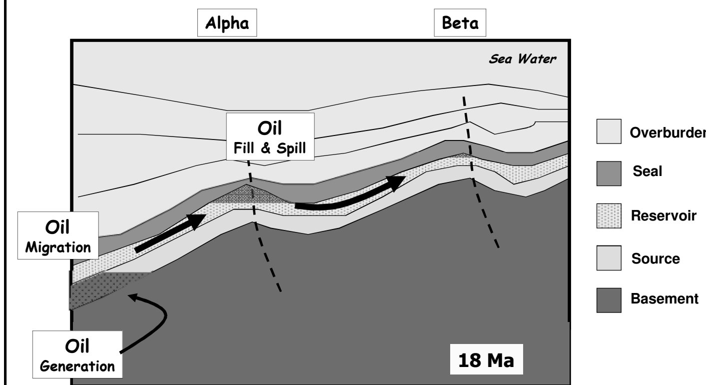


Should we drill Beta?

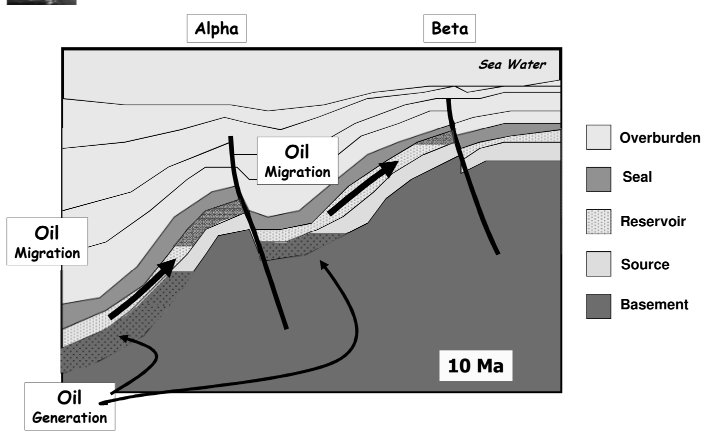
Seismic Line Across 'Alpha'



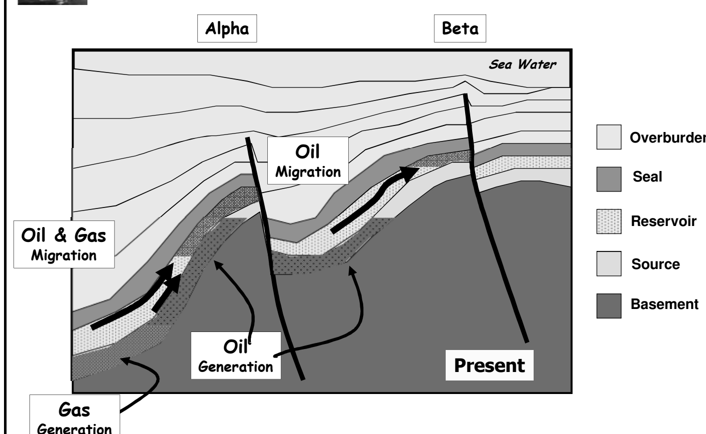
Most-Likely Scenario



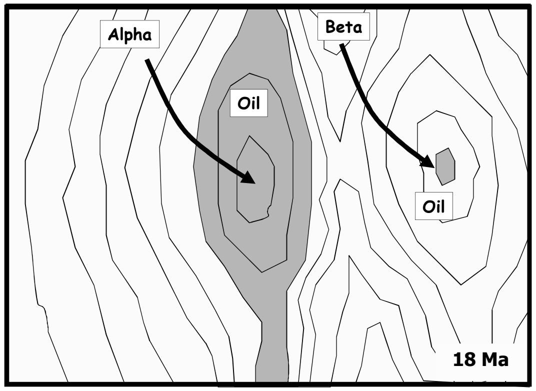
Most-Likely Scenario



Most-Likely Scenario



Most-Likely Scenario



Map of the Reservoir Unit

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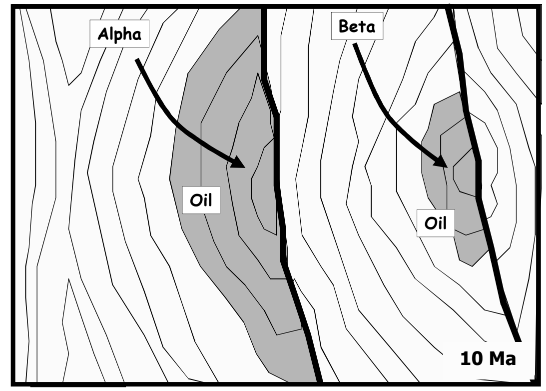
Most-Likely Scenario



Map of the Reservoir Unit

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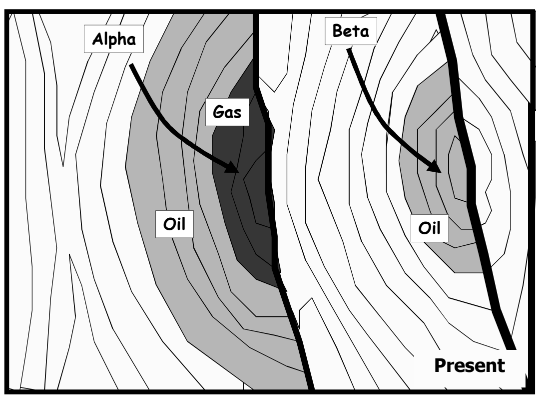
Most-Likely Scenario



Map of the Reservoir Unit

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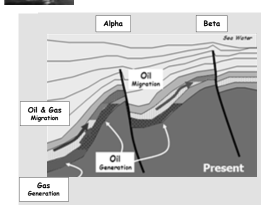
Questions???



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)?

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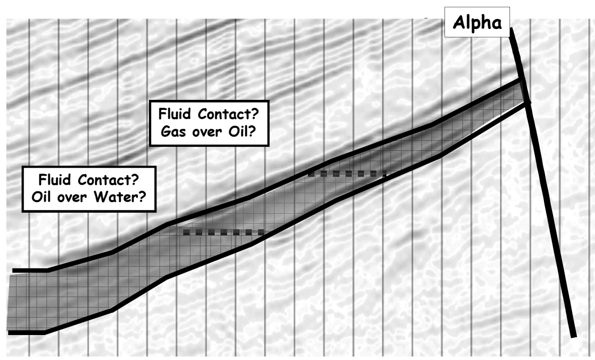
Seismic Line Across 'Alpha'



Maturing a Prospect

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

Deterministic Assessment

Probabilistic Assessment

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 km^2
- 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

Gross Rock Volume: 1850 Mm^3 or 11,100 MB

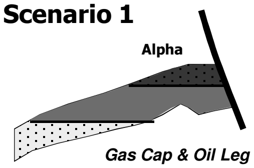
Oil in Place 960 MB

Unrisked Recoverable Oil 320 MB

Unrisked means everything in the HC System has worked!

Scenarios & Probabilities

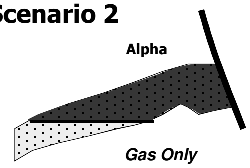
Scenario 1



Gas Cap & Oil Leg

45% Chance of Occurrence

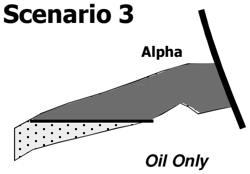
Scenario 2



Gas Only

25% Chance of Occurrence

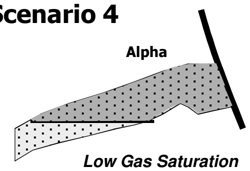
Scenario 3



Oil Only

20% Chance of Occurrence

Scenario 4



Low Gas Saturation

10% Chance of Occurrence

Deterministic Prospect Assessment

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

For our hypothetical Alpha and Beta

ESTIMATES	Alpha	Beta
1. Gross Rock Volume	2.91 km³	2.21 km³
2. Reservoir Volume	1.02 km³	0.66 km³
3. Pore Volume	0.255 km³	0.145 km³
4. In-Place Volume	0.204 km³	0.116 km³
5. In-Place – Barrels	1283 MBO	730 MBO
6. EUR – Unrisked	320 MBO	146 MBO
7. EUR – Risked		

Unrisked means everything in the HC System has worked!

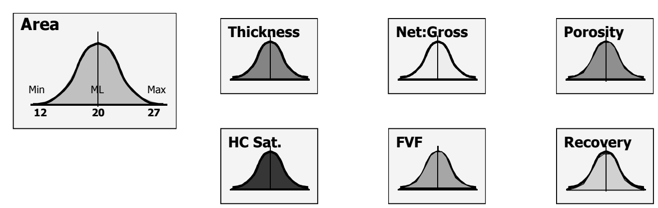
Alpha Prospect Assessment

	Oil (Million Barrels Oil)	Gas (Billion Cubic Ft Gas)	Oil-Equivalent (Million Oil Equivalent Barrels)
Scenario 1 Oil & Gas	240 MBO	120 GCF	260 MOEB **6 GCF = 1 MBO**
Scenario 2 Gas Only	0 MBO	440 GCF	73 MOEB **Uneconomic**
Scenario 3 Oil Only	320 MBO	0 GCF	320 MOEB
Scenario 4 Low Gas Saturation	0 MBO	0 GCF	0 MOEB **Uneconomic**

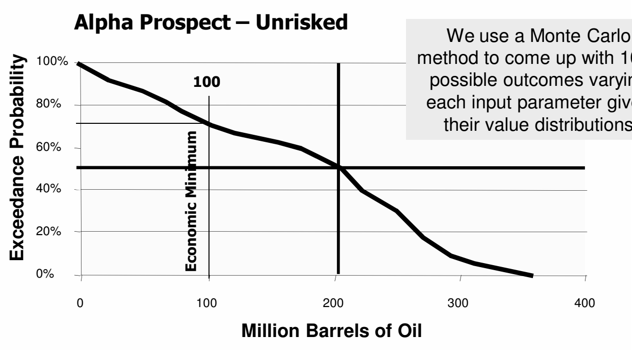
Assuming 100 MOEB is needed to make prospect economic

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



Unrisked Results



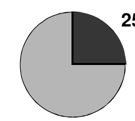
We use a Monte Carlo method to come up with 1000 possible outcomes varying each input parameter given their value distributions

50% Chance of finding 200 MBO or more
75% Chance of finding the economic minimum

Maturing a Prospect

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

How Confident Are We?



9 Key Elements of the HC System

Source Quality	Reservoir Presence	Trap Quality
Source Maturation	Reservoir Quality	Seal Adequacy
HC Migration	Biodegra-dation	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

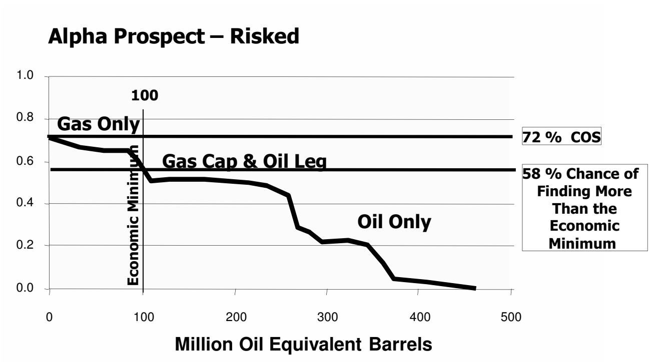
- Alpha's biggest risk is that the fault does not seal
- There is also a chance that the trap is only filled with low saturation gas
  - **Reservoir Presence - - - - 1.0**
  - **Reservoir Quality - - - - 1.0**
  - **Trap Quality - - - - 1.0**
  - **Seal Adequacy - - - - 0.8**
  - **Source Quality - - - - 1.0**
  - **Source Maturation - - - - 1.0**
  - **HC Migration - - - - 1.0**
  - **NOT Low Gas Saturation - 0.9**
  - **NO Biodegradation - - - - 1.0**

chance of success (COS)
0.72

Highest Risk

Some Risk

Risked Probabilistic Assessment Results



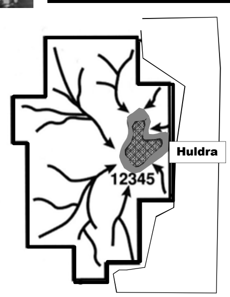
72% Chance to find some hydrocarbons
58% Chance to find 100 MBOE
5% Chance to find 400 MBOE

FWSchroeder 41

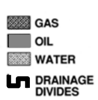
Appendix

FWSchroeder 42

North Sea Example



Schroeder & Sylta, 1993

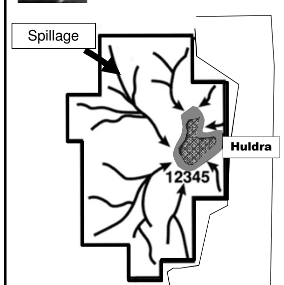


An Example Drainage Polygon:

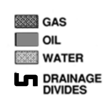
- Has a unique ID number (e.g., 12345).
- Has a trap defined by a culmination depth and a spill/leak depth.
- Has local HC generation (fetch volume).
- Has spillage into it from a deeper drainage polygon.
- Trap pore volume is filled with oil and gas:
  - Filled with oil + dissolved gas.
  - If excess 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.

FWSchroeder 43

HC Drainage



Schroeder & Sylta, 1993

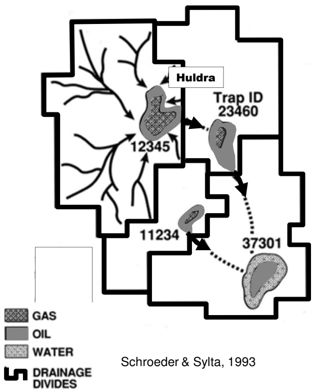


Local Drainage:

- 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

FWSchroeder 44

Drainage and Spillage



Schroeder & Sylta, 1993

HC Spillage:

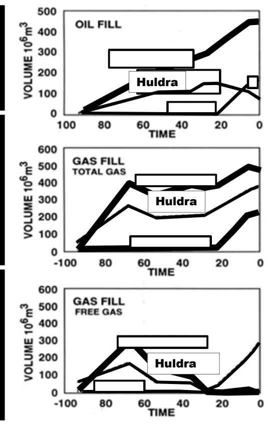
- HC charge to trap
  - Previously stored
  - Incremental drainage
  - Spill into drainage
- Gas volumetrics
  - In-situ gas density
  - Gas in solution
  - Gas leakage through cap
- Spillage out of trap
  - Excess volume
  - Spill direction
  - Oil flushed by gas

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**



Schroeder & Sylta, 1993

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.

FWSchroeder 1

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!

FWSchroeder 2

Your Objective

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

To **Convey** information that

results in **Action**

FWSchroeder 3

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

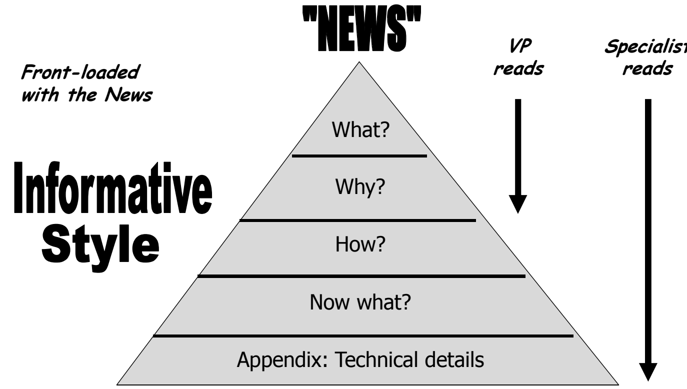
FWSchroeder 4

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



Topics for an IBA Report

6. Topics to be covered in the data analysis include:

   a. Geodynamics, plate tectonic setting & tectonic evolution
   b. Sedimentary basins: classification & tectonic setting
   c. Regional paleogeography
   d. Seismic interpretation
   e. Well log interpretation and correlation
   f. Regional stratigraphy/depositional environments/sequence stratigraphic framework.
   g. Source presence and quality evaluation
   h. Subsidence history and source rock maturation/migration (including 1D basin modeling)
   i. Seal presence and quality evaluation
   j. Trap (structural and stratigraphic) analysis
   k. Formation evaluation
   l. Reservoir presence and quality evaluation
   m. Subsurface fluids & pressure regimes
   n. Dry hole analysis
   o. Prospect evaluation
   p. Risk assessment and volumetric analysis
   q. Final recommendation for business action

An economic analysis is not expected and should <u>not</u> be conducted.

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

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 loose too much time on what you don't need

The Tiger Report

AAPG

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

FWSchroeder 9

The Tiger Report

AAPG

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

FWSchroeder 10

The Tiger Report

AAPG

How do we know

- Location
- Available data
- Play element analysis
- Prospect definition
- Volumetric estimates
- Chance of success determination

FWSchroeder 11

The Tiger Report

AAPG

Now what?

- Proposed wildcat well location
- Cost estimates
- Profit analysis

} **Not part of IBA**

- We are seeking your approval to proceed

FWSchroeder 12

The Tiger Report

Details

- Oral
  - A series of backup slides
- Written
  - Appendix A
  - Appendix B
  - Appendix C
  - Appendix D

FWSchroeder 13

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

FWSchroeder 14

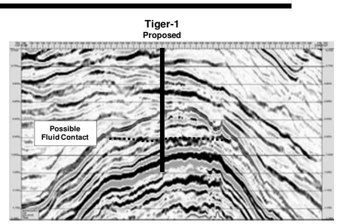
Tiger Wildcat Proposal — Slide 1

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

Risked

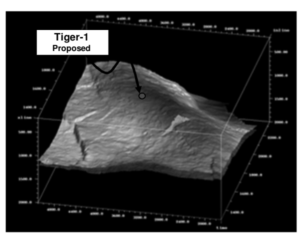
Economic Minimum

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

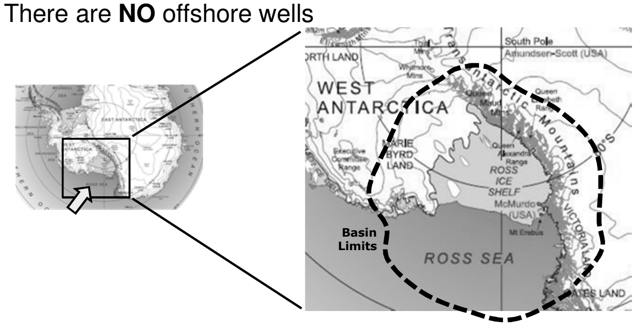
- Chris Jones, Team Lead
- Pat Smith
- Jean White
- Sam Miller
- M. J. Wheeler



FWSchroeder 15

Location

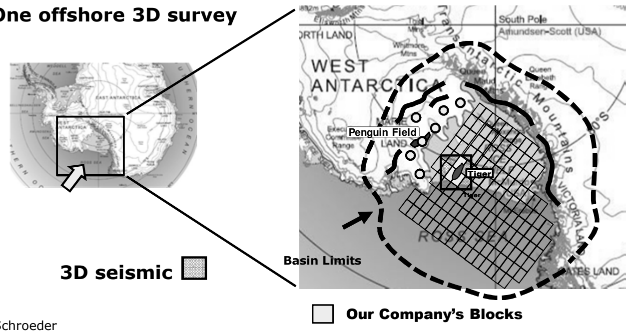
- A third of the Ross Basin extends onshore
- There are many outcrops of Cretaceous and Paleogene rocks
- There are a number of onshore wells; one gas field
- There are **NO** offshore wells



FWSchroeder 16

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

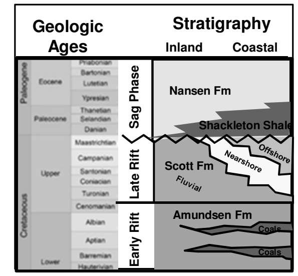


FWSchroeder 17

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 Cret.

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

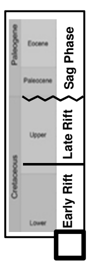


Geologic History Summary
- During the Upper K there was a regression followed by a minor marine transgression
- A major unconformity occurred at the end of the Cretaceous
- The area subsided rapidly, which resulted in a major marine transgression
- As subsidence slowed, a new regression occurred
- During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

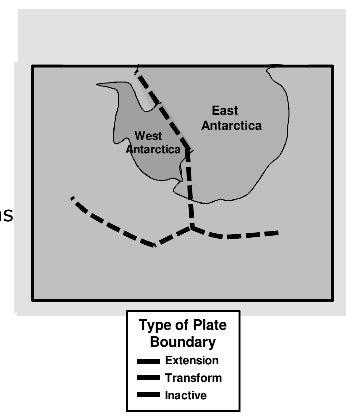
FWSchroeder 18

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



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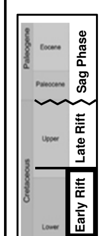
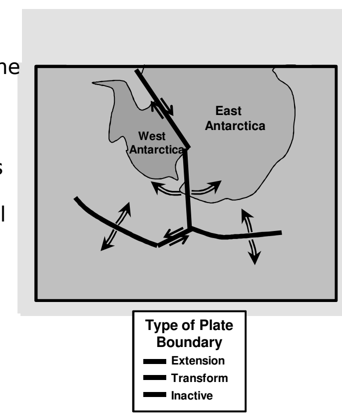
Early Cretaceous – Early Rifting

Amundsen Formation



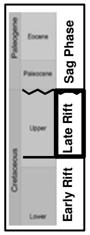
- Rifting commenced in the Ross Sea separating East and West Antarctica
- Early syn-rift sediments including volcano-clastics and major coal seams
- First significant marine incursions



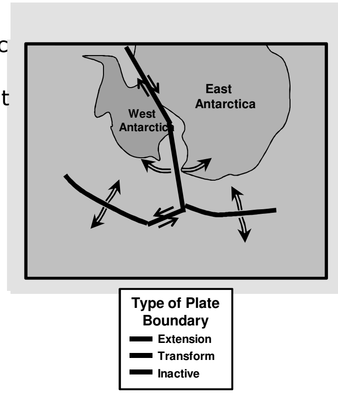
FWSchroeder 20

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



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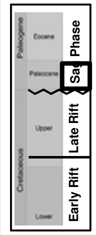
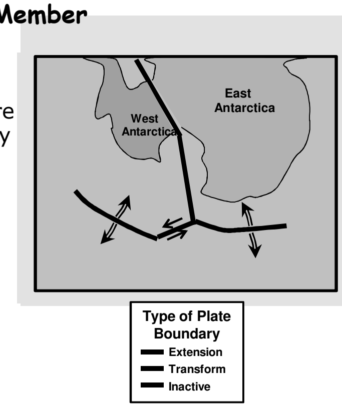
Paleocene – Initial Sag Phase

Nansen FM/Shackleton Member



- Time of a world-class transgression
- Deep marine shales were deposited in the rapidly subsiding basin



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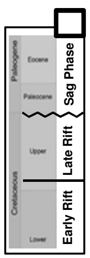
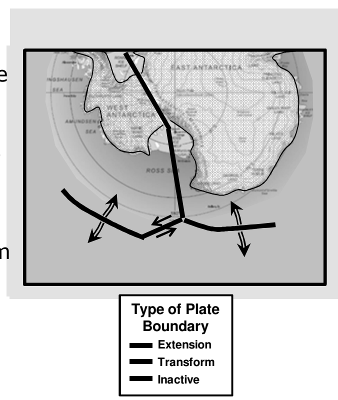
Present Day

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



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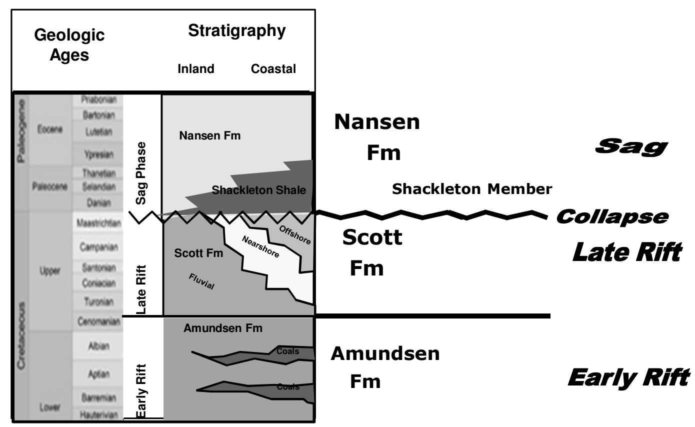
Stratigraphic Chart



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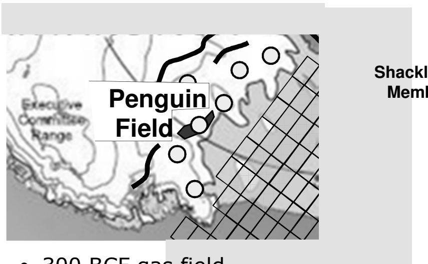
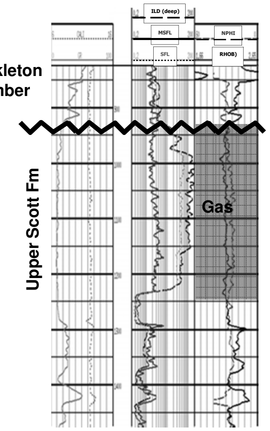
Penguin Field



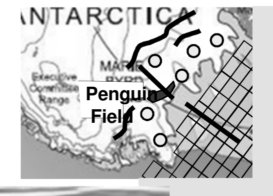


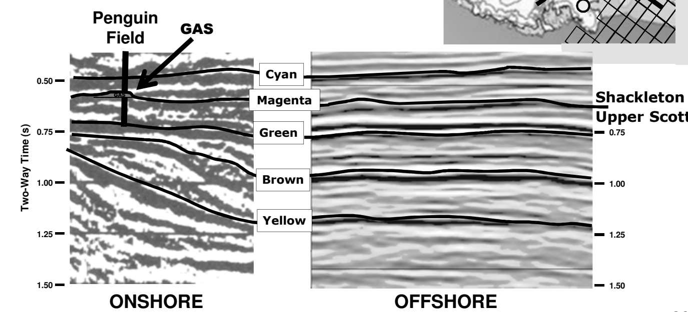
- 300 BCF gas field
- Upper Scott fluvial reservoir;
  Φ =12%, κ = 300 mD
- Source is Amundsen coals;
  Type III, TOC = 35%, HI = 375
- Seal is marine shale of the
  Shackleton Member

FWSchroeder 25

Seismic Through Field

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



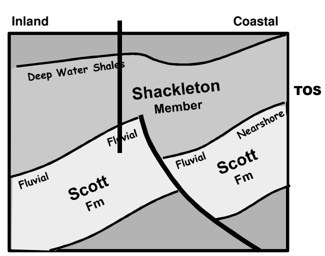


FWSchroeder 26

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

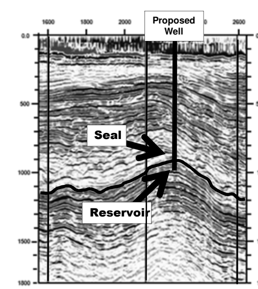
  - **Anticlinal Traps**
  - **Scott Reservoirs**
  - **Shackleton Seals**

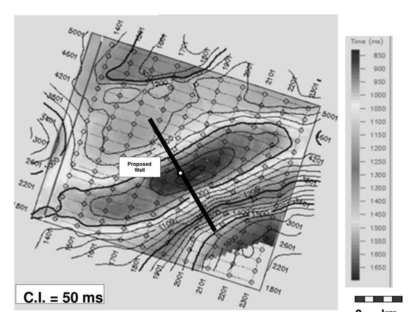


FWSchroeder 27

Trap

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

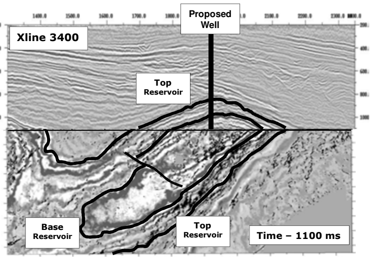




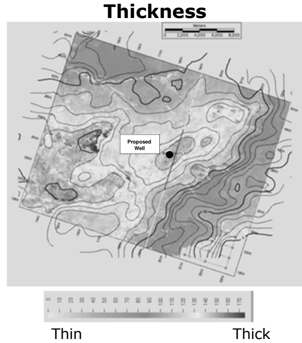
FWSchroeder 28

Reservoir

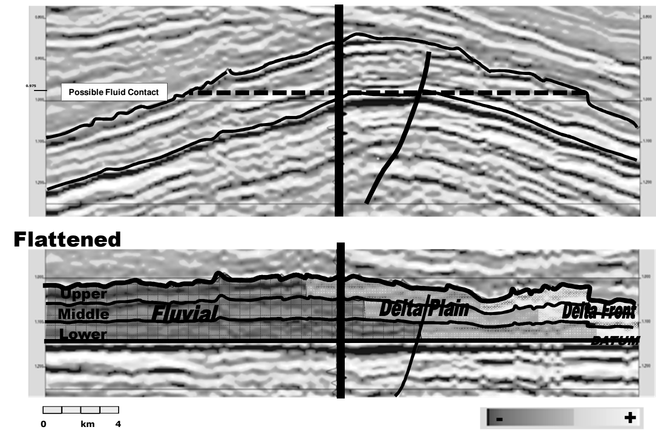
- The Scott Group fluvial to nearshore sandstones are the primary reservoirs



Vertical Time Thickness

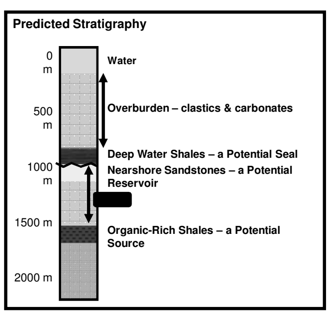


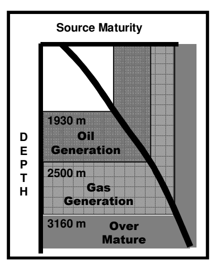
Environments of Deposition



Source

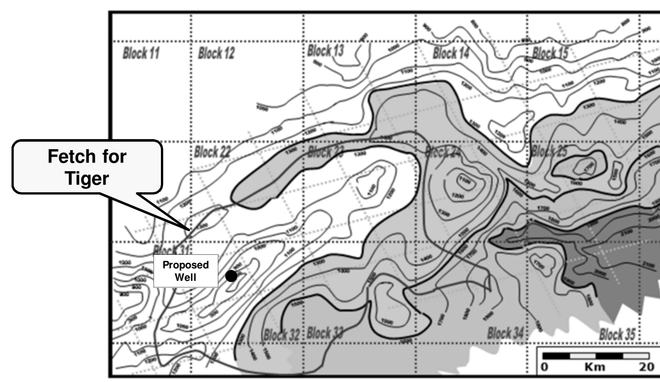
- Coals and coastal plain coaly shales in the Amundsen Fm
- Dominantly terrestrial plant origin with high total organic carbon (TOC) values





Top of Oil Window = 1300 ms
Top of Gas Window = 1600 ms
Top of Over Mature Window = 1900 ms

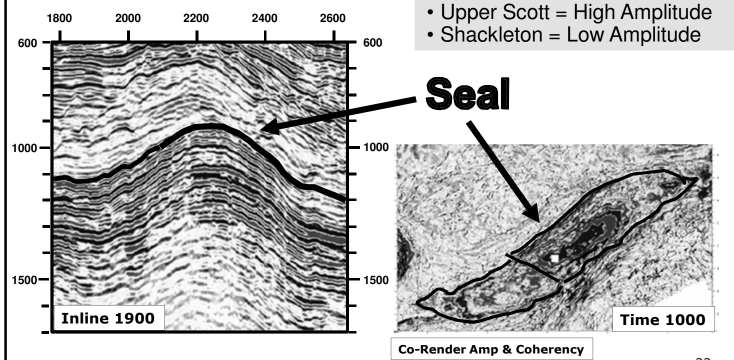
Oil & Gas Generation Windows



Seal

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

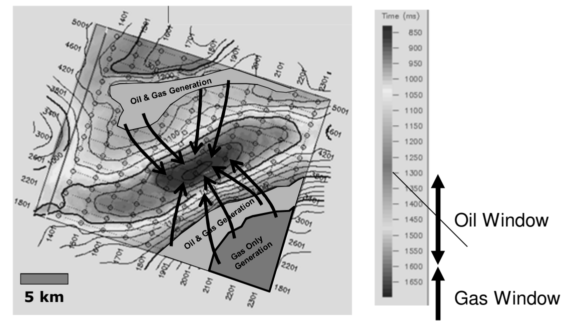
- Upper Scott = High Amplitude
- Shackleton = Low Amplitude



FWSchroeder 33

Maturation & Migration

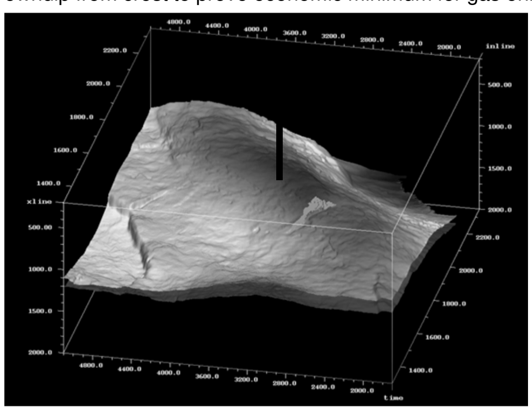
- The major generation and expulsion was initiated in the Miocene
- Peak generation at depths of 4-5 km for oil and 5-6 km for gas



FWSchroeder 34

Proposed Well Location

Downdip from crest to prove economic minimum for gas only case



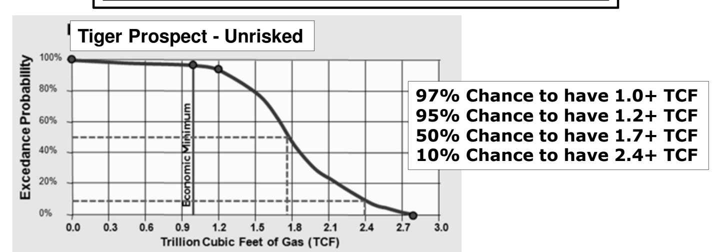
FWSchroeder 35

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

PARAMETER	Most Likely Case	Low-Side Case	High-Side Case
Recoverable Gas at Surface in Bcf	1600	724	2845



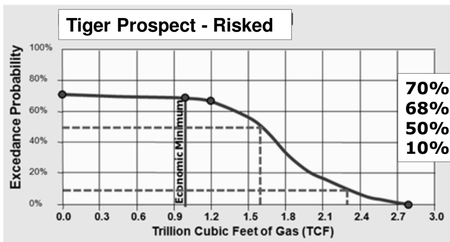
FWSchroeder 36

Risked Reserves

AAPG

Risk Factors

1. Reservoir Presence	0.95	6. Source Maturation	0.95
2. Reservoir Quality	0.95	7. HC Migration	1.0
3. Trap Quality	1.0	8. Not Low Gas Saturation	0.95
4. Seal Adequacy	1.0	9. No Biodegradation	0.98
5. Source Quality	0.90	TOTAL COS	0.72



70% Chance to have 1.0+ TCF
68% Chance to have 1.2+ TCF
50% Chance to have 1.6+ TCF
10% Chance to have 2.3+ TCF

FWSchroeder 37

Summary & Recommendations

AAPG

- 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.

FWSchroeder 38

AAPG

Questions?

FWSchroeder 39