
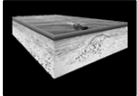
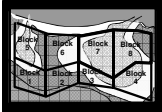
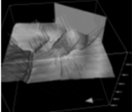
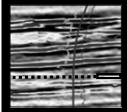


## Welcome





## Petroleum Exploration Using a Field for an Example

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## Logistics




- Emergency Procedures
- Rest Rooms
- Hours
- Breaks

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## Your Instructor




Name: Fred W. Schroeder, Ph.D.

Degrees: BS in Eng. Physics – Lehigh U.  
MS in Marine Geology – Columbia U.  
PhD in Marine Geology – Columbia U.


Experience: 32 years with ExxonMobil Research  
3.5 years with Noble Energy


Specialties: Seismic Interpretation (2D & 3D)  
Seismic Stratigraphy  
Basin Modeling  
Seismic Attribute Analysis  
Volume Interpretation & Visualization

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## My Experience





- G&G studies of numerous basins worldwide
- R&D of interpretation tools & techniques
- Develop & deliver in-house training

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## Course Objective

- This course takes a quick look at what we do in the early stages of exploration
- We will follow an fictitious field, although I have used more modern data and methods than were available when the field was discovered
- We start prior to the first offshore licensing round
- We will progress to the stage of a management review of a wildcat well

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## Course Design

- There are three sessions of about 90 minutes
- There is homework between sessions

### Session I

00-L Introduction
01-L Play Elements (with example)
02-L Introduction to the Ross Basin
03-L Regional Evaluation
03-E Preparing for a Lease Sale (Intro)
05-E Mapping a Prospect (Intro)

### Session II

03-E An Offshore Lease Sale
04-L The Tiger Lead
05-E Mapping a Prospect (Solution)
06-L Source Rocks
06-E Source Mapping & Generation (Intro)
07-L Reservoir Rocks
07-E Reservoir Evaluation (Intro)

### Session III

06-E Source Mapping & Generation (Solution)
07-E Reservoir Evaluation (Solution)
08-L Estimating Ultimate Recovery
08-E Gusher's EUR
09-L Maturing a Lead
09-E Gusher's COS
10-L Management Review

#### Homework

- Exercise 3
- Exercise 5

#### Homework

- Exercise 6
- Exercise 7

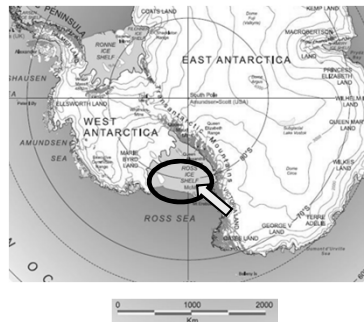
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## Field Location

- Our fictitious field is supposedly in the Ross Basin, offshore Antarctica



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## IBA Preparation

Should you be preparing for an IBA competition, please note:

- I will guide 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 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 Fred's example and win a prize!

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## Lecture 1

# Play Elements with an Example

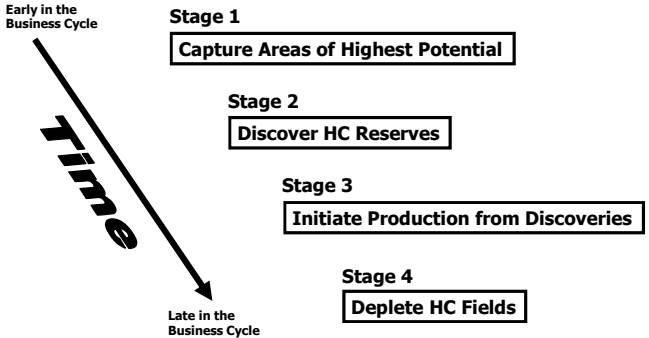
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## Geoscience Work in Industry

The Geoscience Work Process can be subdivided into four (4) main stages that are related to the business cycle of an asset



Early in the Business Cycle

**Stage 1**  
Capture Areas of Highest Potential


**Stage 2**  
Discover HC Reserves

**Stage 3**  
Initiate Production from Discoveries

**Stage 4**  
Deplete HC Fields

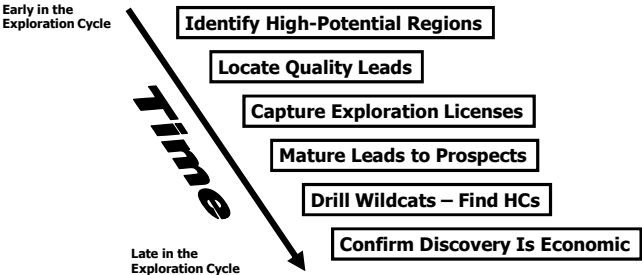
Late in the Business Cycle

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## Exploration Geoscience

- Exploration is charged with finding and confirming new oil and gas fields
- Their goal is to replace the volumes of HC that the company produces so reserves stay flat or increase



Early in the Exploration Cycle

Identify High-Potential Regions

Locate Quality Leads

Capture Exploration Licenses


Mature Leads to Prospects

Drill Wildcats – Find HCs

Confirm Discovery Is Economic

Late in the Exploration Cycle

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## Some Terminology

- **What is a Lead?**
  - A lead is something that geoscientists find that might be a trap holding an economic volume of recoverable oil and/or gas
  - It is worthy of further study, but not ready to propose as a drilling target
- **What is a Prospect?**
  - A prospect is something that has been scientifically matured to the state that we are ready to present it to management as ready to be drilled
  - We have an estimate of what we will recover and a chance of success

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## Stage 1: Capture Opportunities

### Key Questions

1. Of the 700+ sedimentary basins on the planet, which offer the highest potential for undiscovered HCs?
2. Which high potential areas can we hope to operate within, in the near future?
3. Is the land holder (e.g., government) for these accessible areas likely to offer up some exploration licenses?
4. What can we do to get ready to enter this area?

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## Play Elements

- What are Play Elements?
  - A play is a combination of the conditions that make a HC field possible
  - A play element is one of these necessary conditions
  - Different companies use slightly different terminology
- List of Play Elements (**my terminology**)
 

1. Source	4. Seal
2. Reservoir	5. HC Migration
3. Trap	

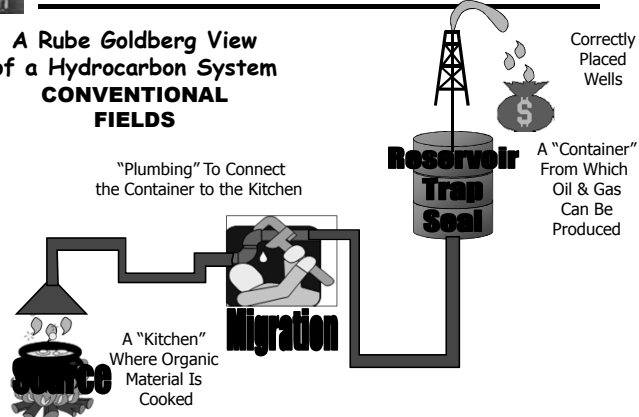
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## What We Need for Success

### A Rube Goldberg View of a Hydrocarbon System CONVENTIONAL FIELDS



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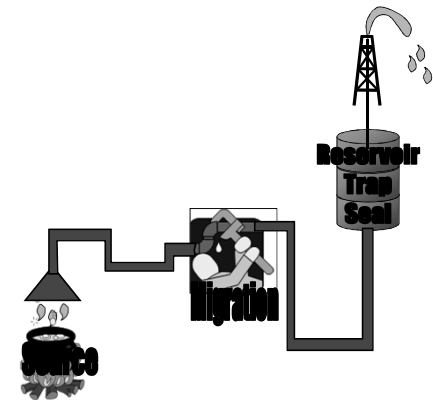
## Elements and Processes

### Essential Elements

- Source rocks
- Reservoir rocks
- Seal rocks
- Overburden rocks

### Major Processes

- Trap formation
- Hydrocarbon
  - Generation
  - Migration
  - Accumulation




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## The Kitchen

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A "Kitchen"  
Where Organic  
Material Is  
Cooked


- **Source**
  - Organic-Rich Rocks, usually shales, best if deposited under anoxic conditions
  - Temperature & Pressure Conditions such that the geochemical transform of organic matter into molecules of oil & gas has occurred

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## The Container

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A "Container"  
From Which  
Oil & Gas  
Can Be  
Produced


- **Reservoir**
  - Porous & Permeable rock that are suitable for producing HCs
  - Most commonly sandstones & some types of carbonates
- **Trap**
  - 3-D configuration in the subsurface where significant amounts of oil & gas is pooled
  - Structural and/or Stratigraphic Traps
- **Seal**
  - Rocks that prevent the leakage of HCs from the trap
  - Most commonly shales and evaporites
  - We need both top seals & lateral seals

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## The Plumbing

---



"Plumbing" To Connect  
the Container to the Kitchen

- **HC Migration**
  - From source (shales) to porous reservoirs
  - Primary mechanism is buoyance
  - Strata-Parallel Component (sand & silt layers)
  - Cross-Strata Component (faults, fractures)

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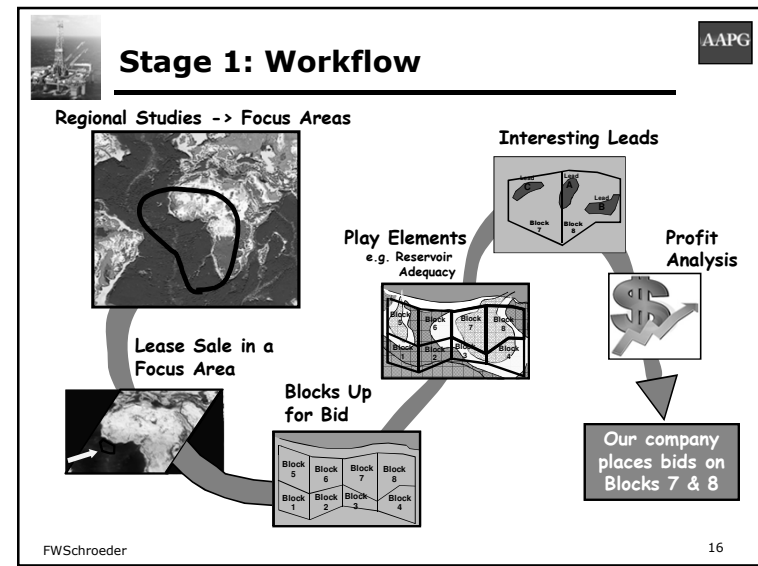
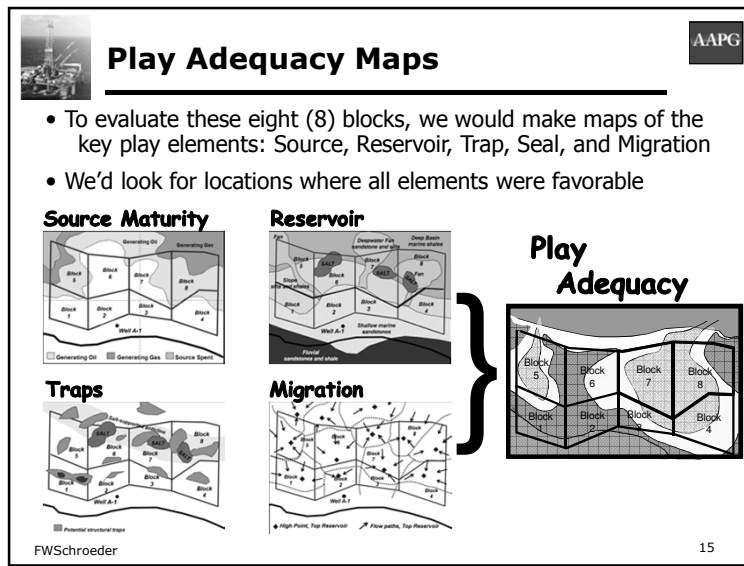
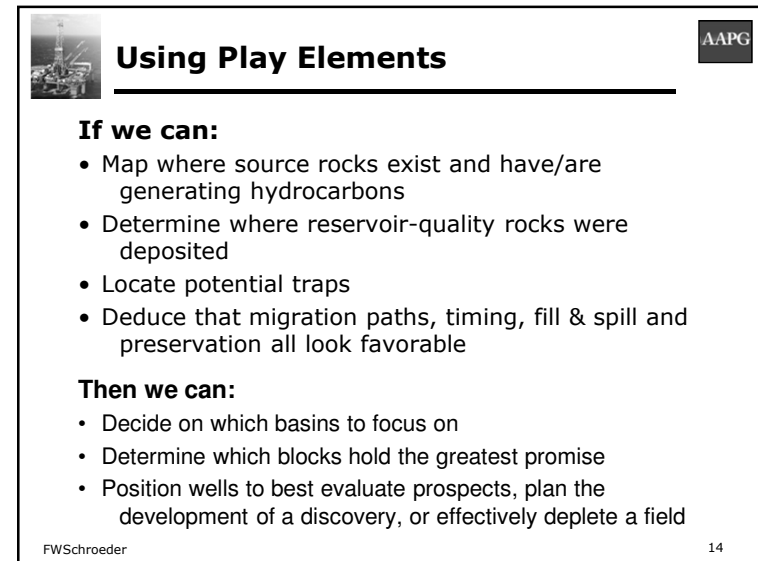
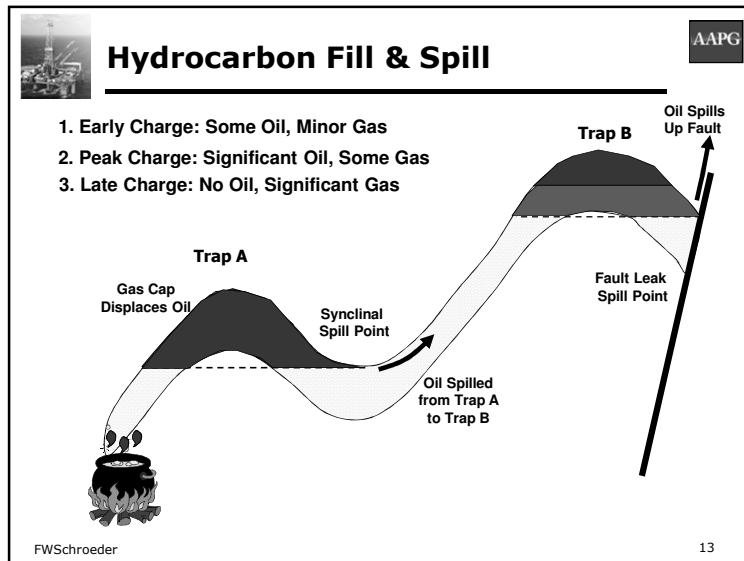
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## Other Important Components

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- **Timing**
  - Did the Trap form before HC Migration began?
- **Fill & Spill**
  - Has HC Generation Exceeded Trap Volume?
  - Has there been Spillage from Trap to Trap?
  - Where is the Oil?
- **Preservation**
  - Has Oil been Degraded in the Reservoir - Thermal Cracking or Biodegradation?

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## Example



### Exercise 2

#### Play Elements – Using Play Adequacy Maps

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## Exercise 2



### Objective

Use a series of seismic interpretation maps to evaluate the HC potential of eight blocks that are open to bidding.

### Final Product

1. List of blocks to drop from further analysis.
2. List of blocks to do more work on.

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## Introduction



Our regional geology team has developed a list of high-potential basins and the Bonanza Basin is high on that list. Now eight blocks are up for bid in this basin.

A team of 5 people have been tasked with evaluating these eight blocks. There is a well just outside the open blocks that encountered a good reservoir and a good source rock. Unfortunately the well was dry. At the well location the source interval is immature (no HC generation).

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## Introduction



A series of maps have been generated based on the well data and a grid of 2D seismic data. Some modeling of source maturation and reservoir porosity as a function of burial depth has also been done.

You will use these maps to decide:

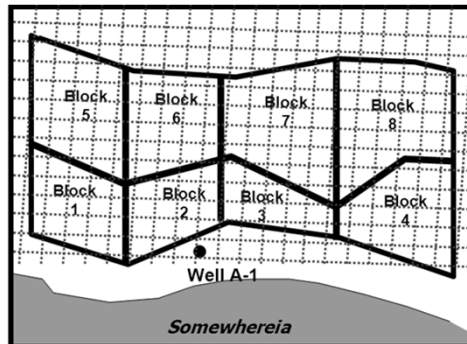
- Which blocks merit further work leading to a bid - Good
- Which blocks show little HC potential - Bad
- Which blocks are in between - Possible

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## Index Map



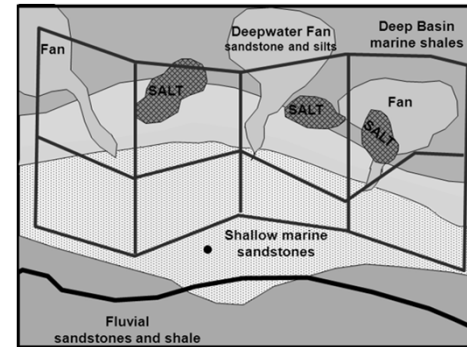
Index map showing the location of the A-1 well, the 2D seismic grid, and the eight open blocks

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## Interpreted EODs



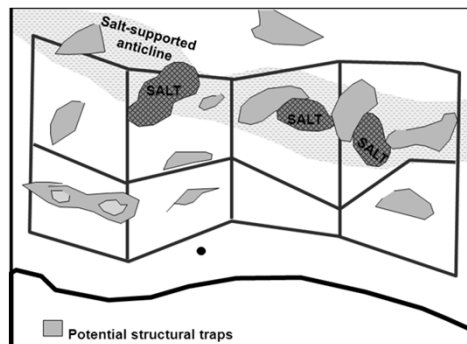
Interpreted depositional environments and inferred lithologies for the primary reservoir interval

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## Structural Traps



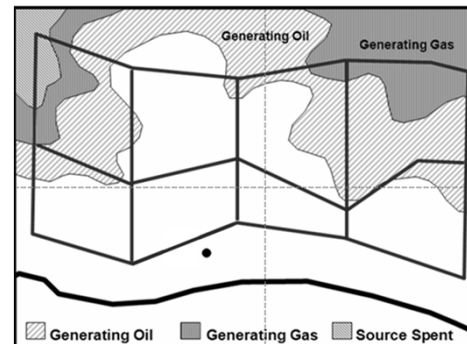
Map of potential structural traps in the Bonanza Basin. Note the salt ridge and anticlines in the northern tier of blocks

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## HC Generation Map

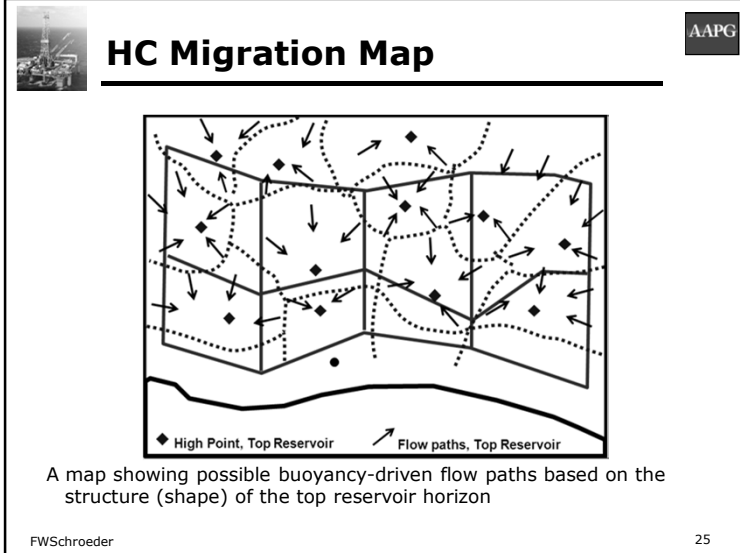


A map showing where oil and gas are currently being generated, based on burial, heat flow, and HC kinetics

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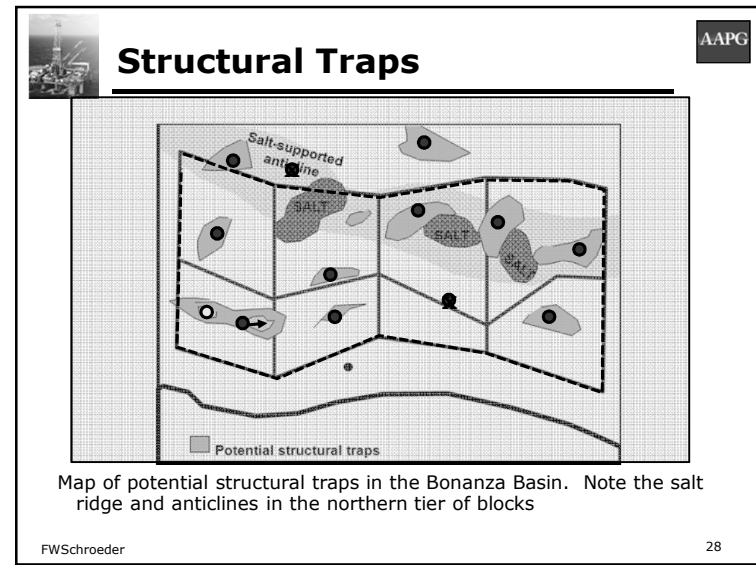
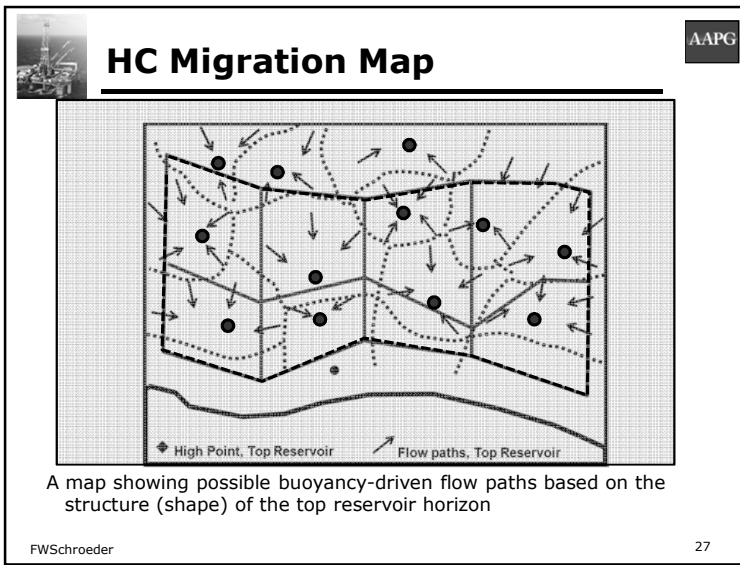


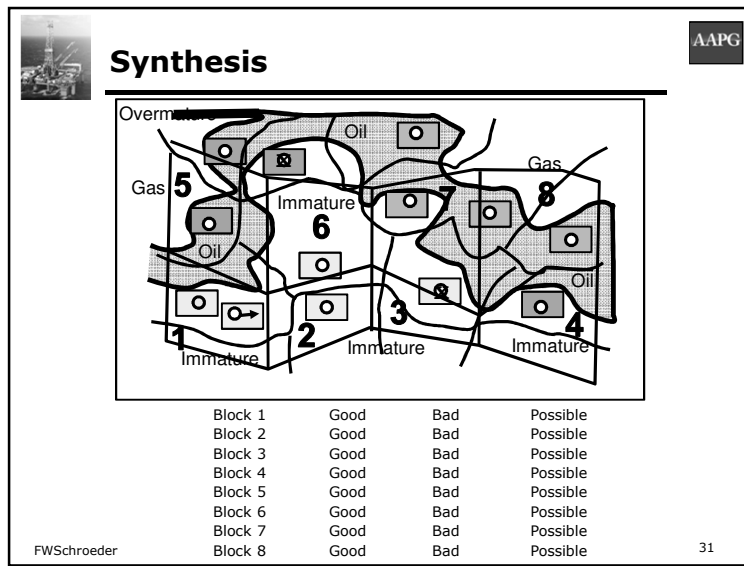
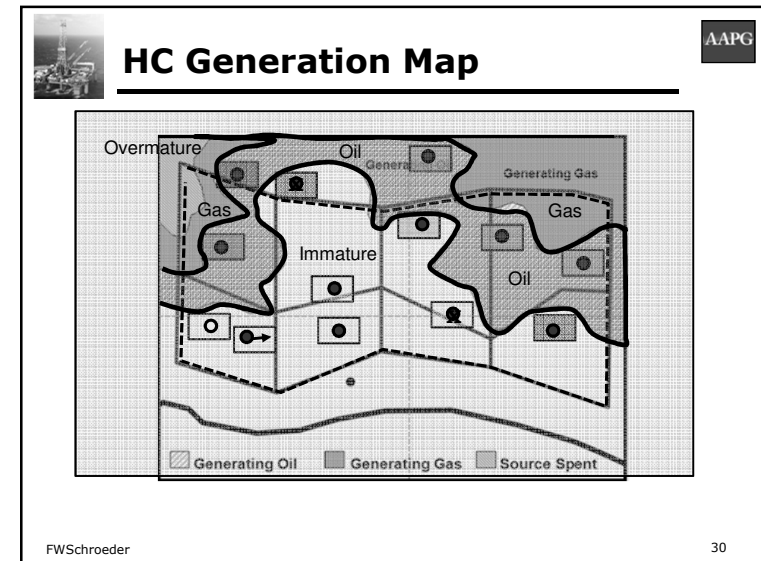
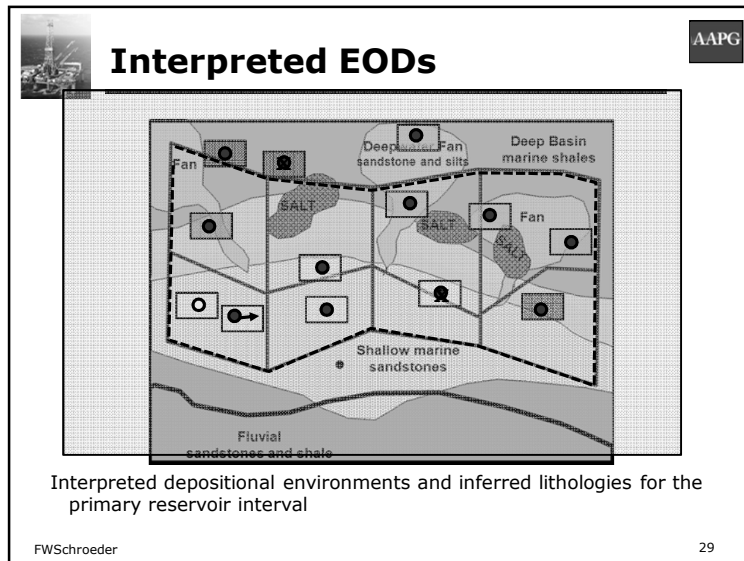
**Your Task**


Based on your analysis, categorize each block into "Good," "Bad," or "Possible." You can circle the appropriate word below.

Block 1	Good	Bad	Possible
Block 2	Good	Bad	Possible
Block 3	Good	Bad	Possible
Block 4	Good	Bad	Possible
Block 5	Good	Bad	Possible
Block 6	Good	Bad	Possible
Block 7	Good	Bad	Possible
Block 8	Good	Bad	Possible


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## Introduction to the Ross Basin



# The Ross Basin


**NOTE:**  
The Ross Basin is real, but the geology and field used as an example is from a different part of the world




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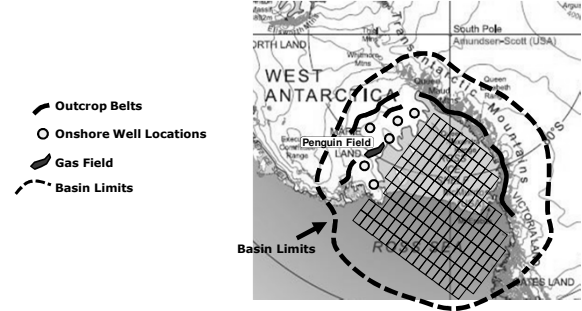
1



## Ross Basin, Offshore Australia




- 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




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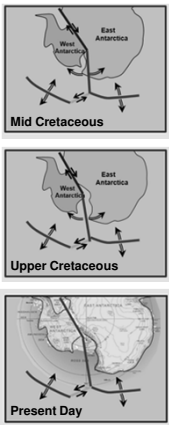
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## Tectonic Setting




- Plate Tectonic Setting
- Basin Evolution
- Stratigraphy




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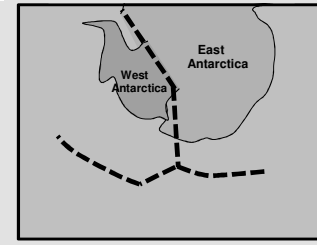


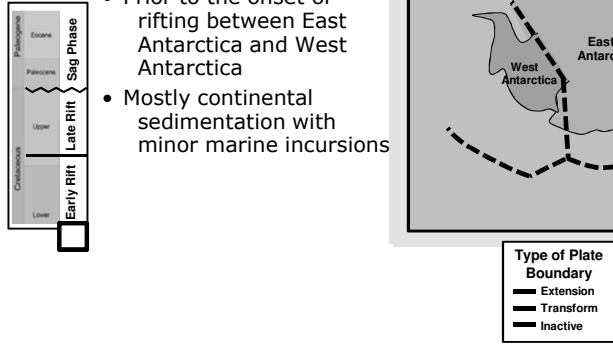
## Late Jurassic



### Hillary Formation


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





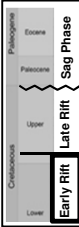
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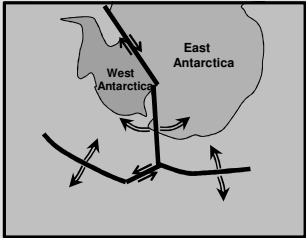


## Early Cretaceous

### 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




**Type of Plate Boundary**

— Extension

— Transform


— Inactive

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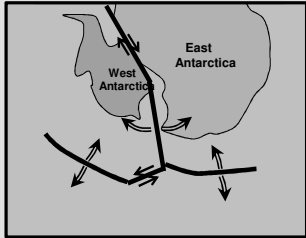


## Upper Cretaceous

### 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




**Type of Plate Boundary**

— Extension

— Transform


— Inactive

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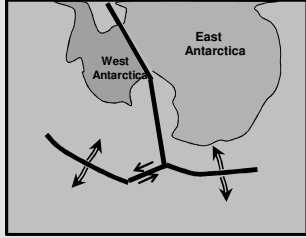


## Paleocene

### Shackleton Member



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




**Type of Plate Boundary**

— Extension

— Transform

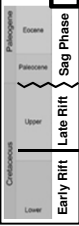
— Inactive

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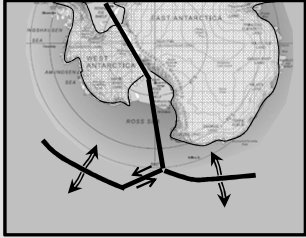


## Present Day

### 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



**Type of Plate Boundary**

— Extension

— Transform

— Inactive

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## Basin Evolution

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- Plate Tectonic Setting
- ✓ • Basin Evolution
- Stratigraphy

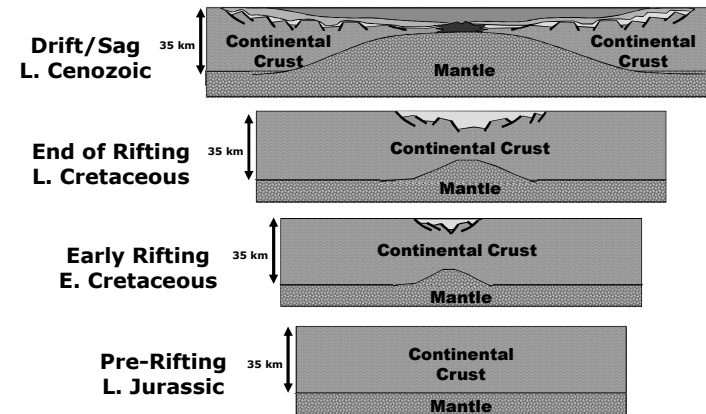
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## Basin Formation

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## Basin Stratigraphy

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- Plate Tectonic Setting
- Basin Evolution
- ✓ • Stratigraphy

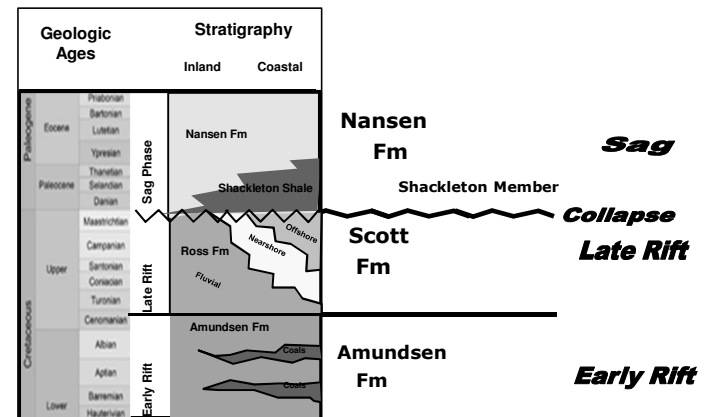
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## Stratigraphy

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## Ross Basin, Summary

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### Tectonic Summary

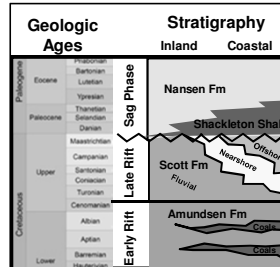
- The basin is an extensional, pull-apart basin
- Rifting started in the Early Cretaceous
- Extension ceased near the end of the Cret.

### 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



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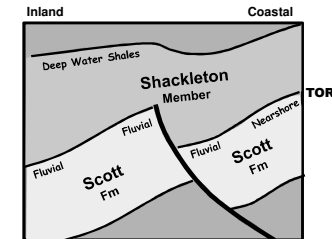


## A Major Unconformity

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### The TOR Unconformity

- The Ross Basin started as a segment of an extensional triple junction
- Active rifting caused basin subsidence from during the Late Cretaceous
- Around K-T boundary, extension ceased in the Ross Basin (a failed rift segment)
- Once extension ceased, the area rapidly subsided and was flooded
- The tectonic readjustments resulted in a major unconformity with erosion of highs on tilted fault blocks and an abrupt change from shallow to deep water facies
- The Upper K Scott Formation has fluvial to nearshore (beach) deposits near the current shoreline – these are potential reservoir rocks
- The Paleocene Shackleton Member consists of deep water shales deposited as the basin rapidly subsided during a major marine transgression – these are potential sealing rocks



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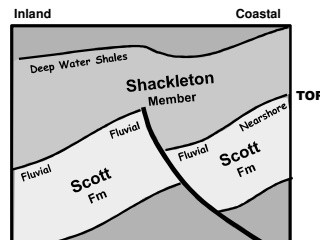


## Trap, Reservoir & Seal

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- 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**



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## Ross Basin Licensing Round

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- The government of Antarctica is offering up 15 offshore blocks in the Ross Basin
- Your company assigned a team of five (5) geoscientists to evaluate the 15 blocks
- The team has compiled data from onshore wells and outcrops and deduced a regional geologic story
- The team will attempt to generate a series of play element maps and identify interesting leads
- For key leads, the team will make some rough estimates of potential HC volumes and risks
- These analyses will lead to a bidding strategy

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## Ross Licensing Round

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The 15 blocks southeast of West Antarctica are open for bids



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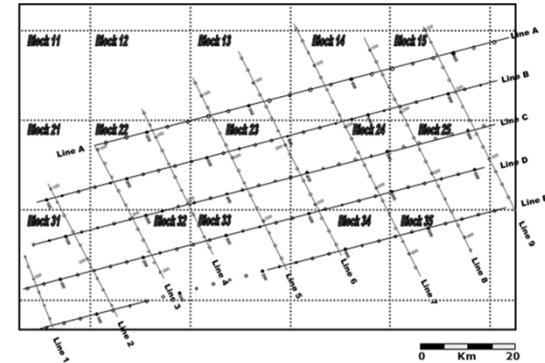
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## Ross Licensing Round

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A coarse grid of 2D seismic lines cover the 15 blocks



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## Lecture 3

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# Regional Evaluation

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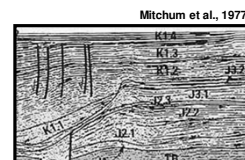
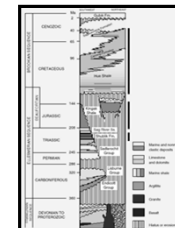
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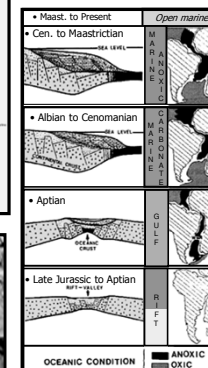
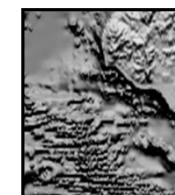
## Mega-Regional Data

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- Geologic Maps
- Plate Tectonics
- Gravity & Magnetics
- Regional Seismic Lines
- Tectonic Evolution
- Stratigraphic Charts
- Paleogeographic Maps
- Etc.



Mitchum et al., 1977b  
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Images Courtesy of ExxonMobil

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## Mega-Regional Analysis

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**Usually mega-regional analyses are performed to:**

- Decide which basins hold the highest potential for discovering & producing oil or gas
- Provide the regional context of a basin or sub-basin so that we can understand the important characteristics of the region
- Provide geologic constraints and the likelihood of HC presence at the beginning of a lease sale evaluation
- To guide step-out wells, i.e., those that extend beyond a known field in search of similar HC accumulations

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## Questions to Address

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- Are there any known HC occurrences in or near the study area?
- What is the availability of outcrop, well, and geophysical data?
- What is the plate tectonic history, including the timing and intensity of structural events?
- What does the local stratigraphic chart look like?
- Do we have possible mature source rocks?
- Are there reservoir quality clastics or carbonates?
- How likely are regional seals?
- What is the weakest play element for this area?

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## Local Data - Surface

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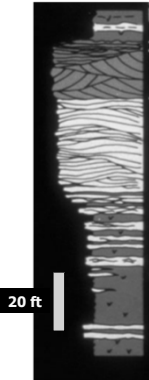
### Surface Observations / Measurements

- Topographic/Bathymetric maps
- Surface geology (structure & stratigraphy)
- Nearby outcrops (or analogs)
- Heat flow measurements
- HC seeps
- Etc.

**Outcrop Studies**



**Measured Sections**



20 ft

Images Courtesy of ExxonMobil  
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## Local Data - Subsurface


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### Subsurface Measurements/Observations

- **Data from Wells**
  - cores, cuttings, logs
  - lithology, ages, geochem, etc.
- **Geophysical Data**
  - Seismic (2D, 3D, 4D)
  - Gravity & Magnetics



**Vibrators – Seismic Sources**



**Logging a Well**

Images Courtesy of ExxonMobil  
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