EXPLORATION

Johan Sverdrup Discovery
Exploration

• What is exploration?
  – Scale Perspective

• What type of data do we use?

• Basic exploration geology
  – What makes a successful prospect?
  – Prospect and Play Analysis
    • Evaluating Volume and risk prognosis

• Statoil Exploration process
Exploration – Visualising and testing the subsurface

• Geology and geophysics
• Creativity
• Big scale operations, seismic and drilling
  • Business process
  • Commercial Valuation
  • Risk Assessment
• Contracts and negotiations
• Element of luck ?
Global – basin – play - prospect – reservoir
DATA

- Satellite Data
- Gravity / Magnetics / Bathymetry / Electromagnetics
- Field Data
- Modern analogues
- Seismic Data
- Well Data

- Field work
- 3D Seismic & bathymetry data
- 3D Seismic Depth Imaging
- Well Data - Wireline Logs

Seismic and Well Data
Changed assumptions

New perspectives

Line of sight to ultimate goal
(Business mindset)
Datasets: Seismic Acquisition

On land

Vibroseis

At Sea

Air Guns

Compressed air is explosively released into the surrounding water.
2D Seismic Acquisition

P = Pressure waves
S = Shear waves
Survey lines often kms apart
Seismic section
• **Regional basin scale surveys.**
  - 5 to 20 km line spacing,
  - 50 to 200plus km lines
  - Used to:
    - Interpret structural trends
    - Basin modelling

• **Semi regional – block wide surveys**
  - 1 to 4 km line spacing
  - 5 to 50 km lines
  - Used for:
    - Mapping prospective structures
2D regional seismic line across the North Sea sedimentary basin

| Shetland Platform | Fladen Ground Spur | South Viking Graben | Utsira High | Stord Basin |

10 km

TGS-NOPEC

Millennium Atlas
2D Seismic Acquisition

Geoseismic Section

- East Shetland Basin
- Viking Graben
- Horda Platform

- Lyell
- Ninian
- Alwyn
- Huldra
- Veslefrikk
- Troll (Upper Jurassic)

Time in seconds

- Quaternary
- Neogene
- Eocene–Oligocene
- Paleocene
- Upper Cretaceous
- Lower Cretaceous
- Upper Jurassic
- Lower/Middle Jurassic
- Triassic

- Primary hydrocarbon migration from source to carrier bed
- Secondary migration within carrier bed/reservoir

- Source rocks
- Oil
- Gas

Approximate level top oil window
Approximate level top gas window

0 10 km
3D Seismic Acquisition

Principle of 3D acquisition

Close spacing between streamers (10s m apart) allowing data to be represented as seismic cubes
3D Seismic Acquisition

Regional mapping & play analysis (prospect generation)

Seismic & geological interpretation at prospect level, ending up in volume & risk analysis (prospect evaluation)

Flat Spot - Interface between Oil and water

Helps to understand complex geology
What are the main ingredients for a successful prospect?

Figure 4.30 – Schematic structural diagram showing evidence of leakage from hydrocarbon reservoirs.
Source

- Presence of oil seeps at surface may be a good indication that there is an active petroleum system in the subsurface.
Stratigraphy - History of depositional environments
SOURCE ROCKS - Decaying organic matter (terrestrial vegetation, plankton, algae, bacteria ..... )

The Upper Jurassic
Kimmeridgian source rock, Kimmeridge Bay England
SOURCE ROCK

What is it? *Organic matter and clay / rock fragments*

• Maturation
• Migration
• Charge
• Preservation

What do we need to know?

• Depositional setting
• Type of organic material
• Depth of burial / age
• Temperature gradient in area
• Composition of rock, Total Organic Carbon content
Kerogen types

<table>
<thead>
<tr>
<th>Environment</th>
<th>Kerogen Type</th>
<th>Kerogen Form</th>
<th>Origin</th>
<th>HC Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic</td>
<td>I</td>
<td>Alginite</td>
<td>Algal bodies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amorphous Kerogen</td>
<td>Structureless debris of algal origin</td>
<td>Oil</td>
</tr>
<tr>
<td>Terrestrial</td>
<td>II</td>
<td>Exinite</td>
<td>Skins of spores and pollen, cuticle of leaves and herbaceous plants</td>
<td>Gas, some oil</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>Vitrinite</td>
<td>Fibrous and woody plant fragments and structureless, colloidal humic matter</td>
<td>Mainly gas</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>Inertinite</td>
<td>Oxidized, recycled woody debris</td>
<td>None</td>
</tr>
</tbody>
</table>
Maturation of organic material

Kerogen types

a

b

0.4% R0 Onset of petroleum generation

Increasing time and temperature

7-50 °C

CO₂ and organic acids

Oil

Natural gas

7-160 °C

Relative yield

C

Increasing time and temperature

CO₂ and organic acids

Oil

Natural gas

Relative yield
RESERVOIR ROCKS - Porous Rocks (sandstones, limestones)
RESERVOIR

• Types of reservoirs
  – Clastic - Aolian, Marine, Fluvial
  – Carbonate

• Depositional Setting
  – Geometry
  – Distribution
  – Quality

• Processes that control erosion and deposition
  – Chemical, Glacial, Wind, Rivers, Waves, Tides, Gravity

In exploration we need to calculate where the reservoir was in the past by using what we see today ......
CLASTIC RESERVOIRS: Aolian Sandstones
CLASTIC RESERVOIRS: Alluvial fans and deltas
CLASTIC RESERVOIRS : Fluvial (river) Sandstones
CARBONATE RESERVOIRS: Corals, reefs and shell debris are main components in carbonate reservoir rocks.
RESERVOIRS: From outcrop to model
Reservoir Properties (Clastics)

- Oil and gas in pore space between sand grains

\[
\text{Porosity} = \frac{\text{Volume of pore space}}{\text{Volume of rock}}
\]

- Porosity decreases with increasing burial depth

- Temperature most important factor. Porosity drops off dramatically when temperature reaches 120 °C

- Quartz overgrowth \( \text{SiO}_2 \)

- Snøhvit, at 2401m. Pure sandstone. Mostly quartz grains – little quartz overgrowths. Grain size ca 0.25mm. Porosity ca 20% Permeability ca 700mD.
**SEAL**: Impermeable rock (i.e. Shale, Mudstones, salt)
TRAP - Geological features that focus and trap hydrocarbons under the seal
TRAP TYPES

ANTICLINAL TRAPS

FAULT TRAPS

SALT DIAPIR TRAPS
TRAP TYPES
TRAP TYPES – SEISMIC SECTIONS

Seismic section from the south of the study area.
PROSPECT ANALYSIS: Volumetric

Gross rock volume

Net to Gross

Porosity

Hydrocarbon saturation

Oil shrinkage /

Formation volume factor

Gas-oil-ratio

GRV \times \frac{N\text{-}G}{1} \times \Phi \times Shc \times \frac{1}{Fvf} \times RF = \text{Recoverable oil/gas}

Gross Rock Volume \times \text{Net to gross} \times \text{porosity} \times \text{hydrocarbon saturations} \times \text{formation volume factor} \times \text{recovery factor}
Basin, play and prospect interrelationship

A play is an assessable area with similar geological controls on reservoir, trap and source. A play is usually tied to one specific stratigraphic interval.

A prospect is a possible petroleum trap with a mappable, delimited reservoir rock volume, i.e. covered by sufficient data of adequate quality to map and calculate reservoir rock volumes.

Families of prospects within one play with shared play risk and interdependencies
PLAY RISK : Critical Risk Maps (Traffic Light Maps)

Individual Components:
- Seal
- Reservoir
- Source

Green area: Favourable
Yellow area: uncertain
PLAY RISK: Critical Risk Maps (Traffic Light Maps)

- **Reservoir**
- **Source**
- **Seal**

Green area: Favourable
Yellow area: uncertain
Red area: Unfavourable
**PROSPECT ANALYSIS : Risking**

**Probability Evaluation**

<table>
<thead>
<tr>
<th>Event</th>
<th>Probability</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(Reservoir)</td>
<td>P(res) = 0.7</td>
<td>P(res) = 0.7</td>
</tr>
<tr>
<td>P(Seal)</td>
<td>P(seal) = 0.9</td>
<td>P(seal) = 0.9</td>
</tr>
<tr>
<td>P(Source)</td>
<td>P(source) = 0.6</td>
<td>P(source) = 0.6</td>
</tr>
</tbody>
</table>

**Example:**

- **P(play) = 0.38**
- Chance for a working play (somewhere)

**P(prospect) = 0.43**
- Chance for a prospect success
  - Given that the play works

**P(discovery) = 0.16**
PROSPECT ANALYSIS: Volumetric output from Monte Carlo simulation

Minimum – Most likely – Maximum (Parameters)

Probability Distribution

Monte Carlo simulate in GeoX

P90 – Mean – P10 (risked and unrisked)
Technical & economical evaluation

- Geological/geophysical evaluation
  - Volumes & probabilities
- Reservoir evaluation
  - Recoverable resources
  - Reservoir quality
  - Production profile
  - No. of wells
- Facilities design
  - Cost estimation
  - Schedule
  - Transport solution
- Exploration / development drilling
  - Drilling costs
- Reservoir evaluation
  - Recoverable resources
  - Reservoir quality
  - Production profile
  - No. of wells
- Economic assumptions
  - Price
  - Inflation & exchange rate
  - Taxation
  - Discount rate
  - Tariffs

EXPECTED NET PRESENT VALUE

KPI's

Sensitivity analysis
THE EXPLORATION VALUE CHAIN

• Requirements for DGA: Approval to develop a business opportunity
• Requirements for DGB: Approval to negotiate
• Requirements for DGC: Decision to access a new exploration opportunity
• Requirements for APx: Approval to initiate well planning
• Requirements for APy: Approval to commit to drilling a well
• Requirements for APz: Approval to start appraisal of a discovery
• Requirements for DG0: Approval to enter the feasibility phase
Process in a license round

- Invitation/announcement
- Pre-qualification
- Preparation, data acquisition, evaluation
- Establishment of partnerships
- Priority, recommendation for bidding
- Application, documentation, bid
- Announcement of bidding results
- License negotiations
- Award, work programme, start-up
- Partnership agreements
- Success or failure; development/production/abandonment or relinquishment
Summary: Tasks in Exploration

- Regional mapping
- Play analysis
- Prospect mapping
- Seismic Interpretation
- Log analysis/petrophysics
Summary:
Tasks in Exploration

- Volume and risk analysis (prospect evaluation)
- Well planning, follow up
- Post well assessment
- Appraisal of discovery
Ultimate aim: Exploration Success!
Unconventional Hydrocarbons

- The development and application of new technology led to commercially access hydrocarbons previously thought of as unproducible
- Now evaluating more opportunities, mainly in the USA but also globally
  - Early entry, inexpensive land acquisition
  - Upside potential from applying modern and new technology
• Thank you