Prospect evaluation, resource assessment and risking

Prospect evaluation

Knut Henrik Jakobsson
Norwegian Petroleum Directorate
Purposes of prospect evaluation by the government

• Basis for recommendation for which blocks should be awarded and proposals for work commitment for licenses

• Basis for evaluation of applications for licenses or bidding rounds

• A state participation can be decided on basis of the evaluation carried out by the government in addition to the applicants/bidders
The Norwegian licensing round

NPD performs own evaluations of announced areas. This forms an important basis for the evaluation of applications.
Volumetric calculation

What is the recoverable hydrocarbon quantities of this accumulation?
The Volumetric Function

\[ R_{vol} \times N/G \times \text{por} \times S_{hc} \times F.v.factor \times \text{Rec.f.} \]

Recoverable resources

In-place resources (HCPV at surface conditions)

HCPV (hydrocarbon porevolume)
HCPV
(hydrocarbon pore volume)

Rock$_{vol}$ x Net/Gross x porosity x Saturation$_{hc}$

trap
definition

reservoir
parameters
The rock volume

Interpretation and mapping
• Seismic interpretation
• Digitizing, map construction
• Depth conversion

Geometric description
• Vertical closure
• Spillpoint relations
• Trap fill
• Uncertainties in interpretation, mapping and depth conversion
The trap

The volume between the top surface and the HC-contact minus the volume between the bottom surface and the HC-contact

ROCK VOLUME OF THE TRAP =

The volume between the top surface and the HC-contact

minus

the volume between the bottom surface and the HC-contact
The maps

Top surface

Bottom surface

A bottom surface map is not required, when:
- the reservoir thickness > vertical closure
- the reservoir thickness is constant
Gross rock volume, some North Sea fields

Troll
Frigg
Heimdal
E. Frigg

Gross rock volume, mill m³
HCPV
(hydrocarbon pore volume)

Rock_{vol} \times \text{Net/Gross} \times \text{porosity} \times \text{Saturation}_{hc}

trap definition

reservoir parameters
Reservoir description

Simplified lithostratigraphy

GR       Sonic
Reservoir parameters

- Reservoir thickness (constant or variable)
- Net/gross ratio (average)
- Porosity (average; > cut-off value)
- HC-saturation (average)
Gross thickness

- Should be taken care of in the mapping procedure...
**Net pay**

**NET PAY =**

*The total thickness of all reservoir units (a-h) with* 
*porosity > threshold value and* 
*permeability > threshold value*
Porosity

- Calculated from electric well logs
- Core measurements

Average porosity larger than cut-off value
Measured porosities and permeabilities are plotted in a XY-diagram...

...in order to establish the cut-off value of efficient porosity
Hydrocarbon saturation is the pore volume fraction which contains hydrocarbons

\[ S_{HC} = 1 - S_{water} \]

- Hydrocarbon saturation \((S_{HC})\) is estimated from log analysis
- Only zones with efficient porosity are included
**Spread in input data**

<table>
<thead>
<tr>
<th></th>
<th>min.</th>
<th>expected</th>
<th>max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>rock volume</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>net/gross ratio</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>porosity</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>hydrocarbon saturation</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

= Hydrocarbon pore volume (HCPV)
In-place resources

- When we move hydrocarbons (HCPV) from the reservoir to the surface, physical conditions as pressure and temperature are changed...
  - *the oil volume is shrinking, and*
  - *the gas volume is expanding*
Oil to the surface...

Surface conditions:
- $P$ (surface)
- $T$ (surface)
- $V$ (surface)

Reservoir conditions:
- $P$ (reservoir)
- $T$ (reservoir)
- $V$ (reservoir)

Diagram:
- Oil to the surface
- Surface conditions
- Reservoir conditions
- Ass. GAS
In-place resources

In-place resources =

HCPV x Formation volume factor

- **“GOIP”** - Gas Originally in-place
- **“STOOIP”** - Stock tank Oil originally in-place
Recoverable resources

Recoverable resources =

In-place resources \times\text{ recovery factor}

Depending on drive mechanisms and production strategy, the recovery factor in general varies:

- between 50 and 80 % for gas
- between 25 and 70 % for oil
Recovery factors for some Norwegian oil fields

Middle Jurassic sandstones

Cretaceous chalk (carbonates)
Recoverable and in-place resources

mill Sm$^3$ o.e.

- Ekoisk
- Stavfjord
- Troll V.
- Gullfaks
- Oseberg
- Eldfisk
- Valhall
- Ula

- Yellow: resources remaining in res.
- Red: recoverable resources
HCPV - prognosis vs result

- There is clearly a tendency to overestimate HCPV
- The same conclusion can be made for BRV, HCCOL, and reservoir thickness
- The wider result distribution as compared to prognosis distribution indicates that industry estimates a too narrow range of most likely outcomes
Conclusions,
- volume assessments

• As explorers, we find less than we predict.

• Explorationists put too narrow ranges on possible outcomes for field sizes and volumetric parameters.

• The above statements are generally valid for any play and trap type, phase, pre-drill probability of discovery and distance to nearest well, however there is a tendency to do better in regions of longer exploration history.

• Bulk Rock Volume (and behind that hydrocarbon column) is clearly the parameter explaining most of the differences between pre- and post-drill hydrocarbon pore volume.
Recommendations, - volume assessments

- We need to improve our volume and parameter estimations!

- Expand ranges of possible outcomes for the volumetric parameters. Our prediction capabilities are poor.
  - Uncertainties related to seismic interpretation, depth conversion, and petrophysical parameter prediction are larger than what is generally perceived

- Spend the time evaluating a prospect according to the importance of the parameters.
  - Bulk Rock Volume should get the highest attention
Risking resources
- geological risk analysis

Inger Fjærtoft
Norwegian Petroleum Directorate

Petrad course: Policy and management of petroleum sector development,
Stavanger
September 2006
Risk analysis

What is the chance of finding the minimum amount of recoverable hydrocarbons as estimated in the prospect assessment?
Some Definitions

“There is a *RISK* that I am going to fall off this cliff and I am *UNCERTAIN* how far it is to the bottom!”
Risk - Probability

Probability = 1 - Risk
Success rate

Success rate = \(\frac{\text{no. of hits}}{\text{no. of trials}}\) = \(\frac{8}{14} = 0.57\)
Probability categories

Stochastic probabilities
- measured values
- success rates, etc

Objective probabilities
- logical arguments,
- analogue events, etc

Subjective probabilities
- beliefs,
- “guts feeling”, etc
The independent risk factors
- NPD’s risk factors

**Probability of discovery:**

\[ P = P_1 \times P_2 \times P_3 \times P_4 \]

...where:

- **P1** - probability of efficient reservoir
- **P2** - probability of efficient trap
- **P3** - probability of efficient source & migration
- **P4** - probability of efficient retention after accumulation
Probability of discovery

The estimated prospect probability is not the probability of making a discovery, but:

The probability of finding at least the minimum quantity of hydrocarbons we estimated in the resource assessment.
Reconstruction of the hydrocarbon accumulation process

- P1: deposition of reservoir
- P2: trap formation
- P3: generation, migration and accumulation of hydrocarbons
- P4: retention of hydrocarbons after accumulation
Sum up - Main principles

Independent risk factors for:

The probability of finding at least the minimum quantity of hydrocarbons we estimated in the resource assessment.
Probability of discovery

- High risk prospects are risked too low
- Low risk prospects are risked too high
Prospect prognosis and drilling results:
Analysis of discoveries from 1990-2002

In place (Mill. b o.e.)

- Total
- Oil
- Gas

Prognosis prior to drilling: 50%
Status 2002: 35%
50%
85%