Prospect evaluation, resource assessment and risking

Prospect evaluation

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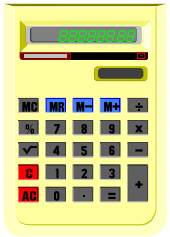
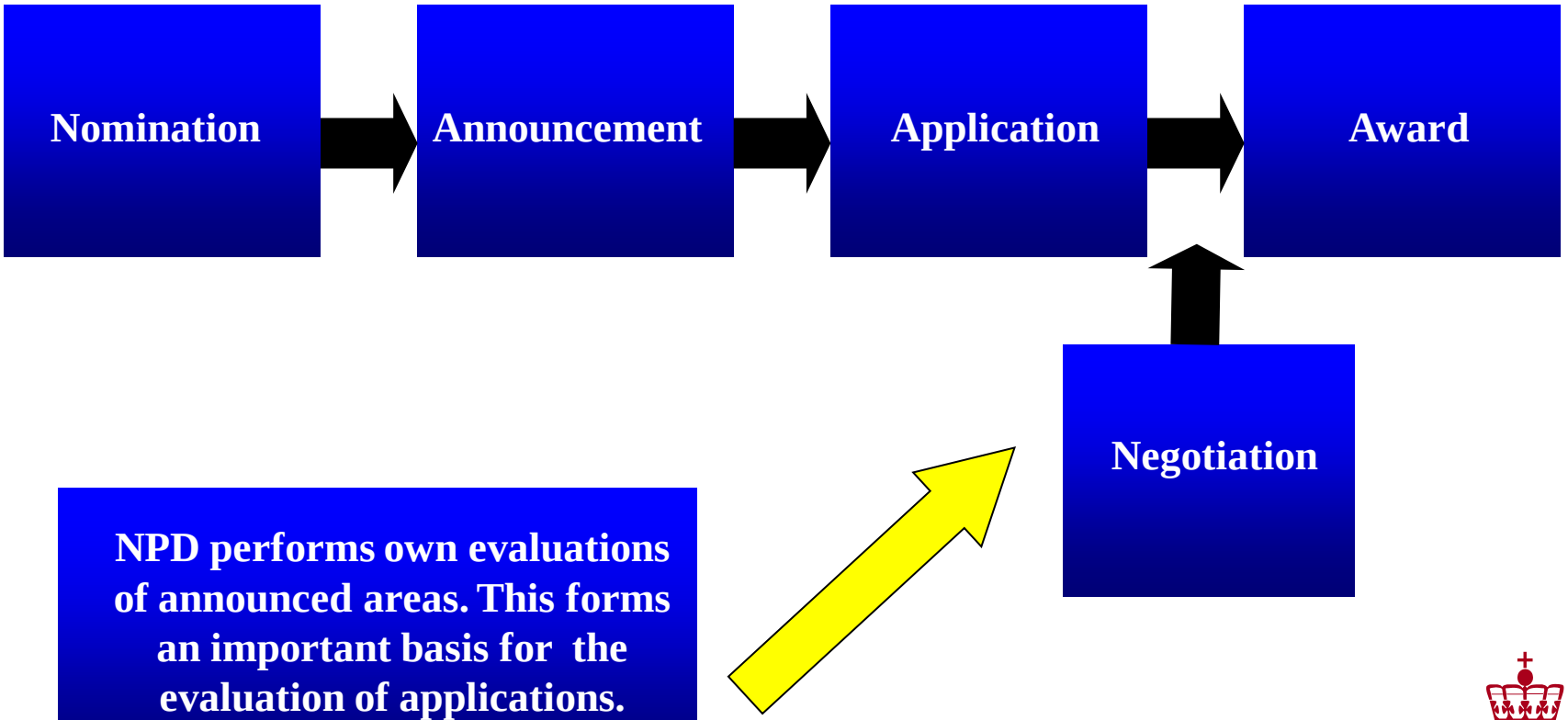
Purposes of prospect evaluation by the government

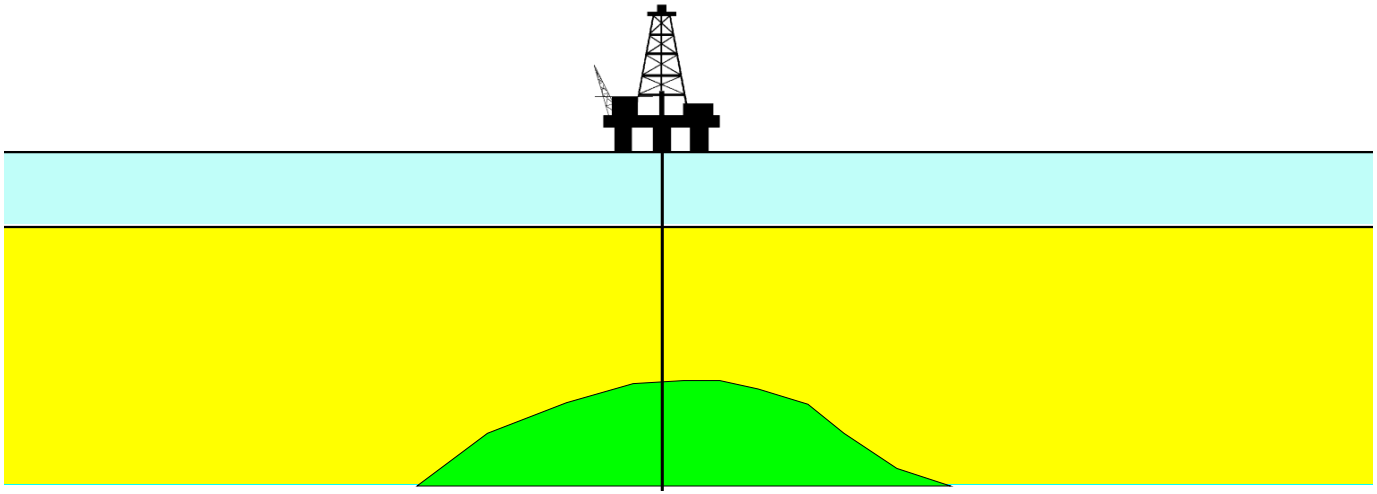


- Basis for recommendation for which blocks should be awarded and proposals for work commitment for licenses
- Basis for evaluation of applications for licenses or bidding rounds
- A state participation can be decided on basis of the evaluation carried out by the government in addition to the applicants/bidders

The Norwegian licensing round



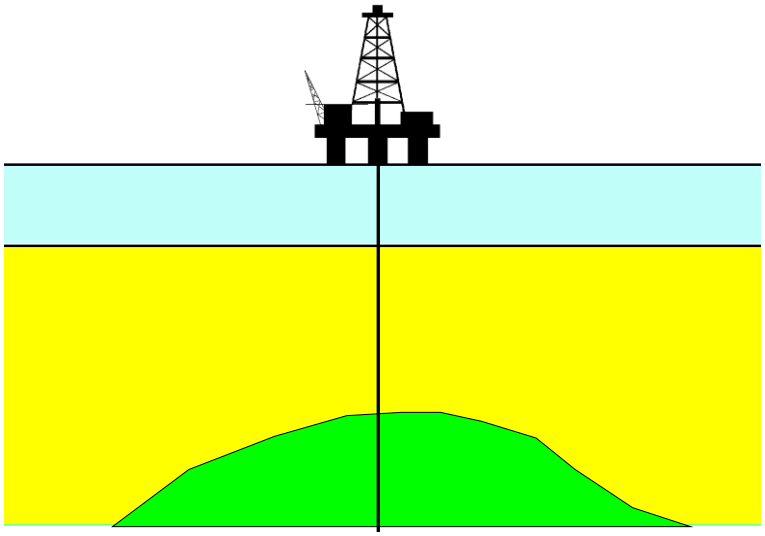
Volumetric calculation



What is the recoverable hydrocarbon quantities of this accumulation ?

The Volumetric Function

R_{vol} x N/G x por x S_{hc} x F.v.factor x Rec.f.



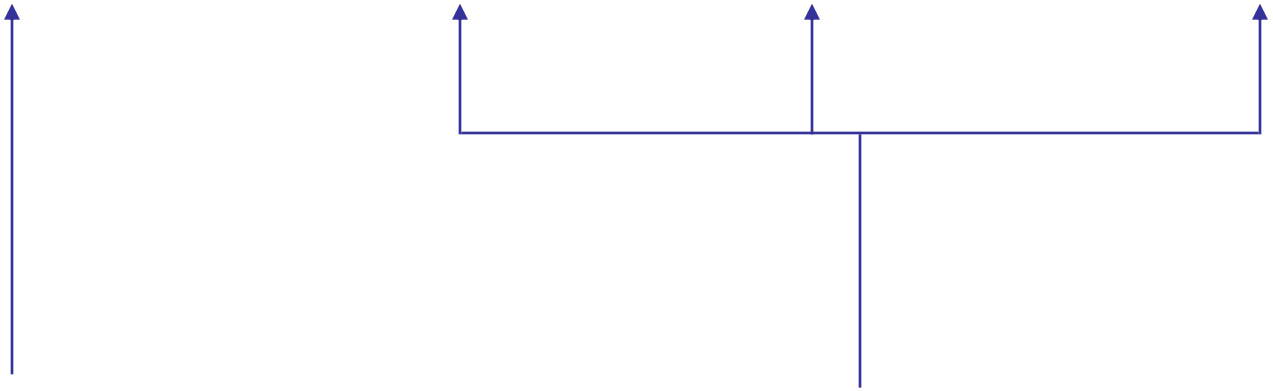
Recoverable resources

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

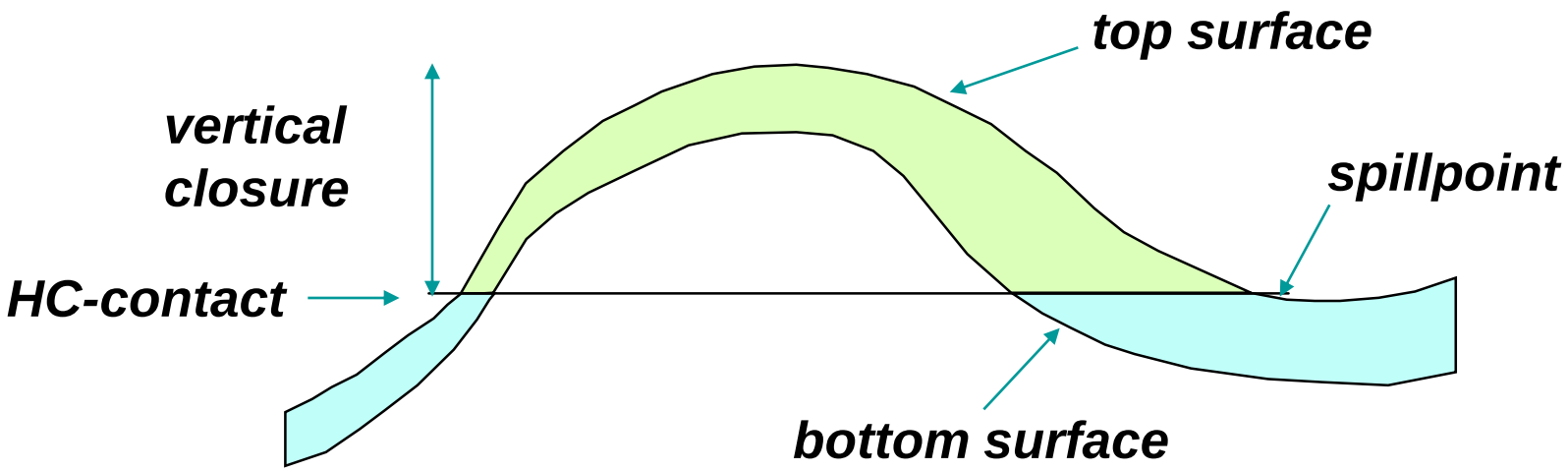
Interpretation and mapping

- Seismic interpretation
- Digitizing, map construction
- Depth conversion

Geometric description

- Vertical closure
- Spillpoint relations
- Trap fill
- Uncertainties in interpretation, mapping and depth conversion

The trap



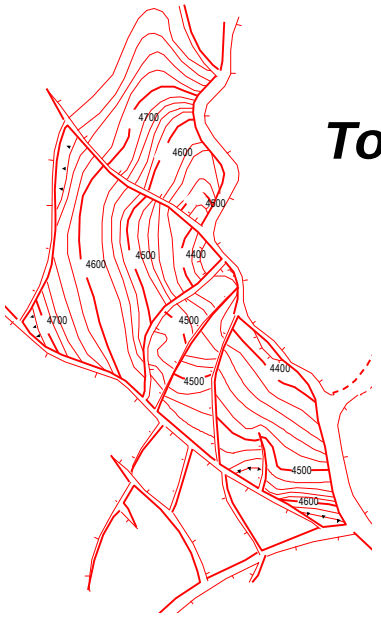
ROCK VOLUME OF THE TRAP =

The volume between the top surface and the HC-contact

minus

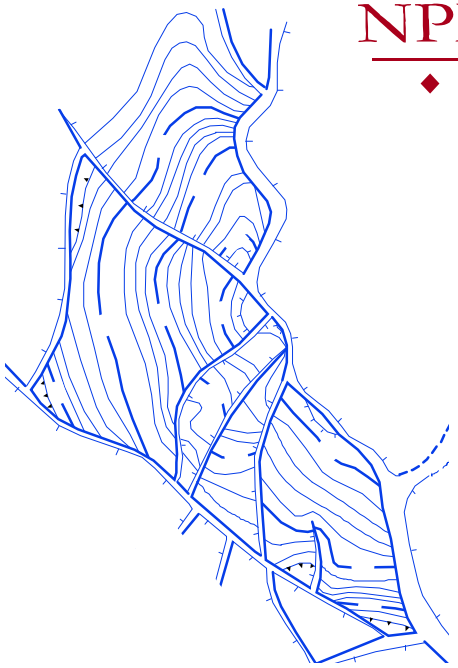
the volume between the bottom surface and the HC-contact

The maps



Top surface

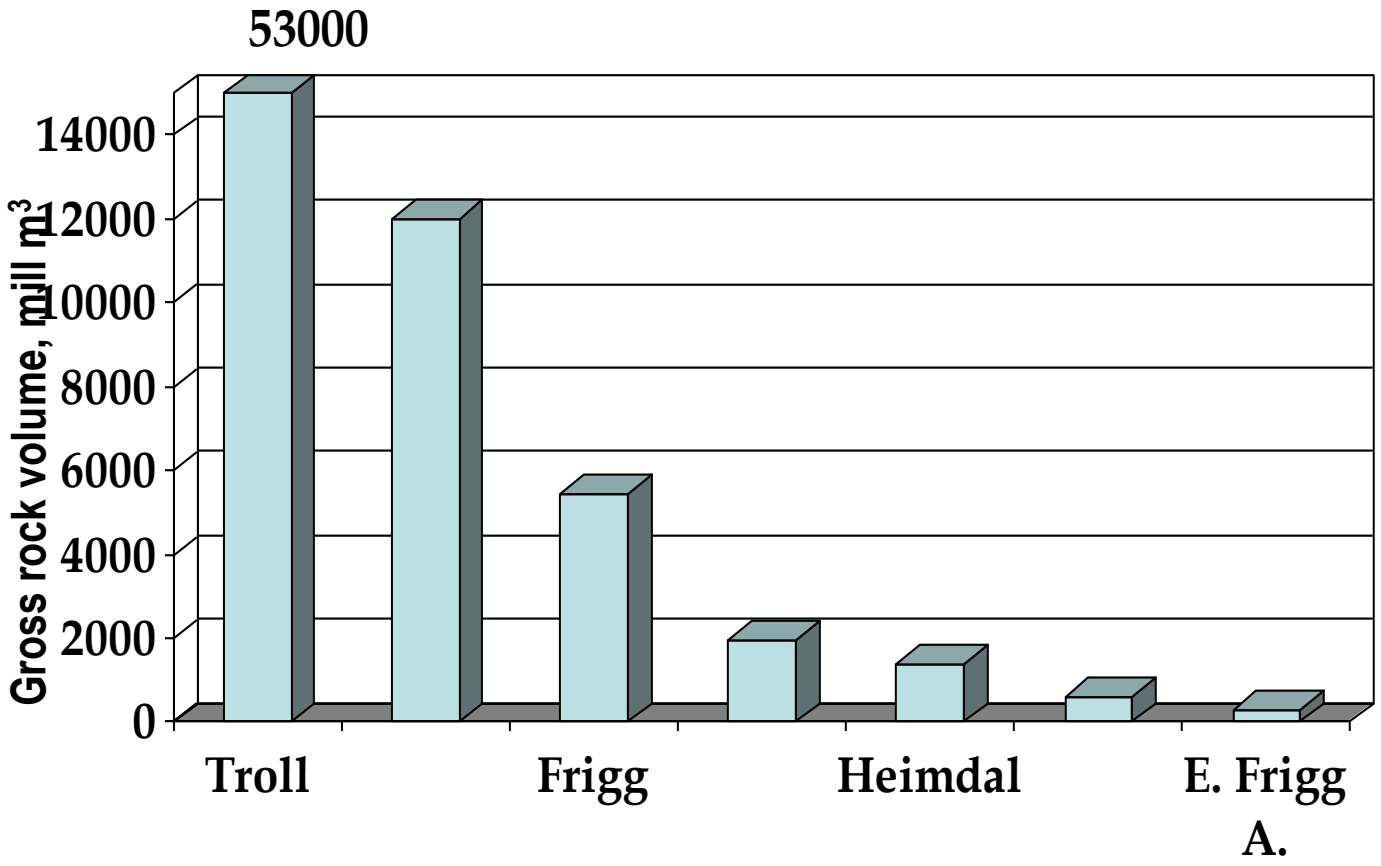
Bottom surface



A bottom surface map is not required, when:

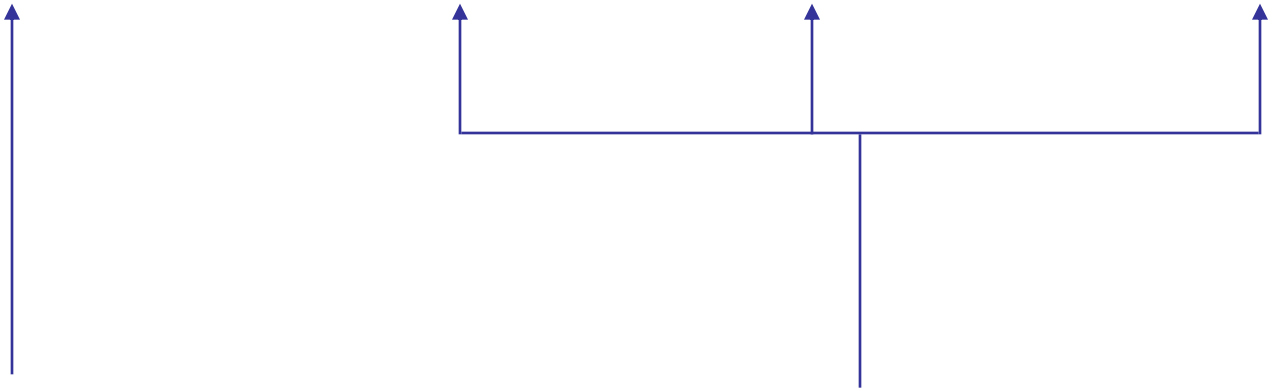
- **the reservoir thickness > vertical closure**
- **the reservoir thickness is constant**

Gross rock volume, some North Sea fields



HCPV
(hydrocarbon pore volume)

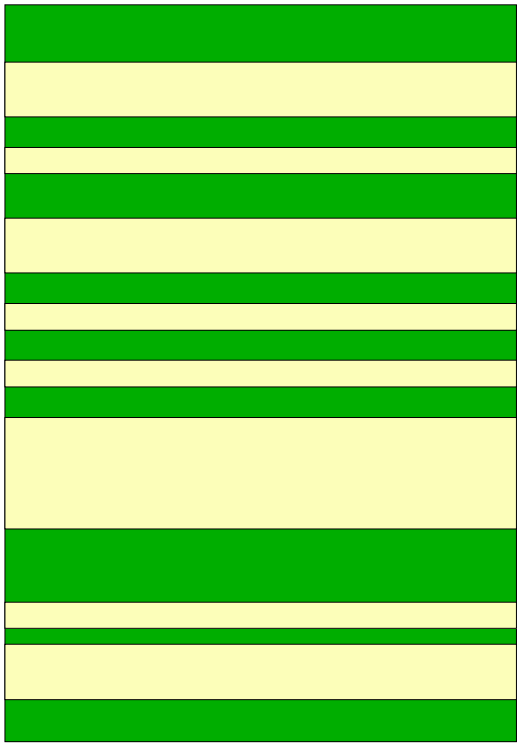
$$Rock_{vol} \times Net/Gross \times porosity \times Saturation_{hc}$$



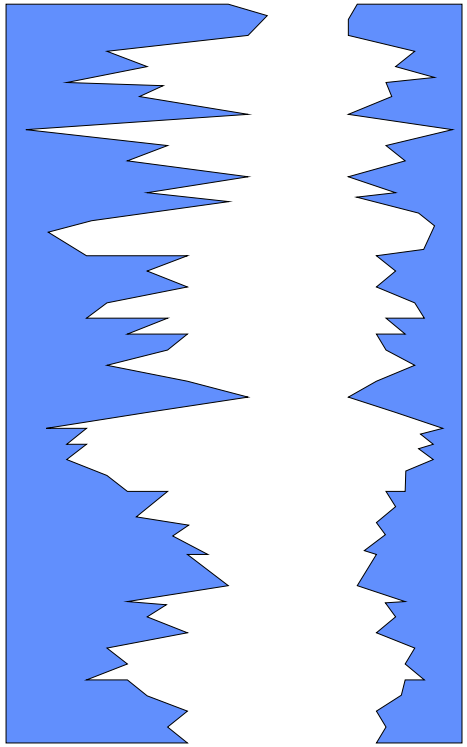
trap definition

reservoir parameters

Reservoir description



Simplified litostratigraphy

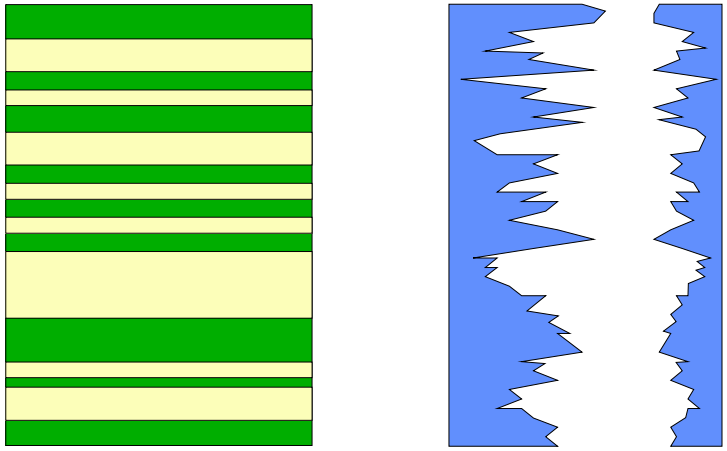


GR

Sonic

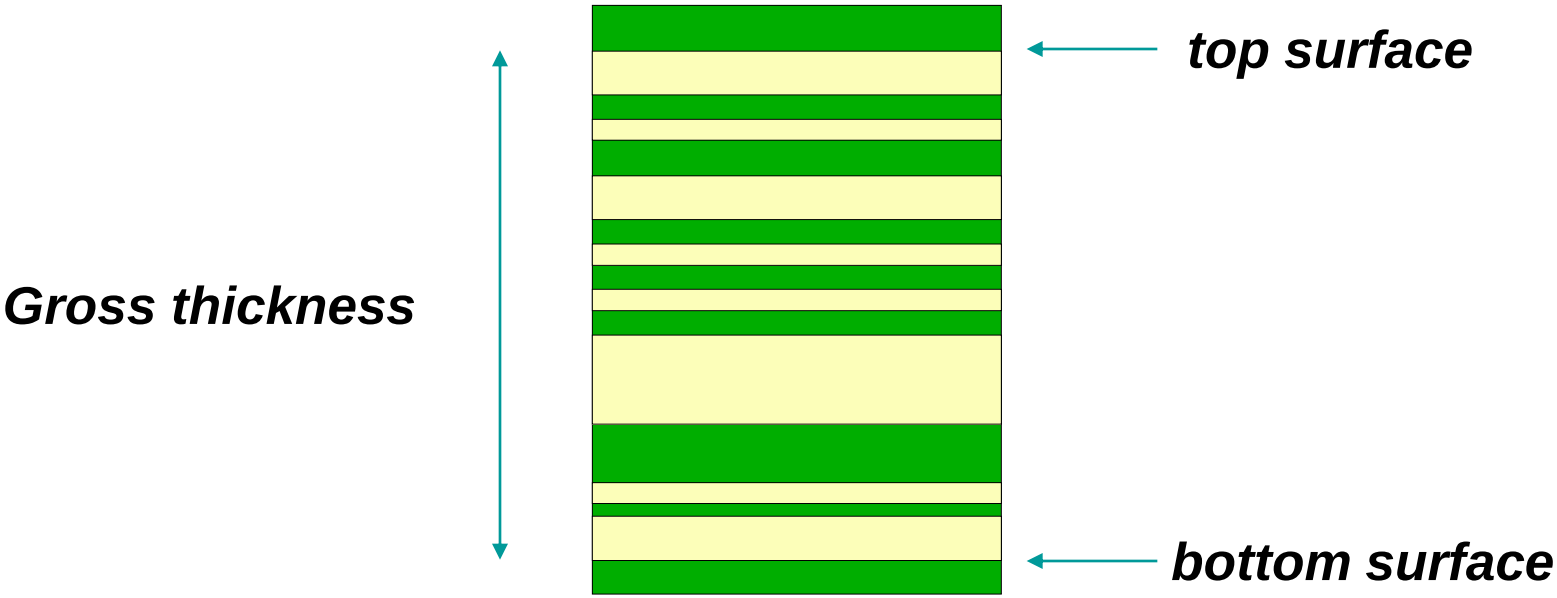
Reservoir parametres

- 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...**

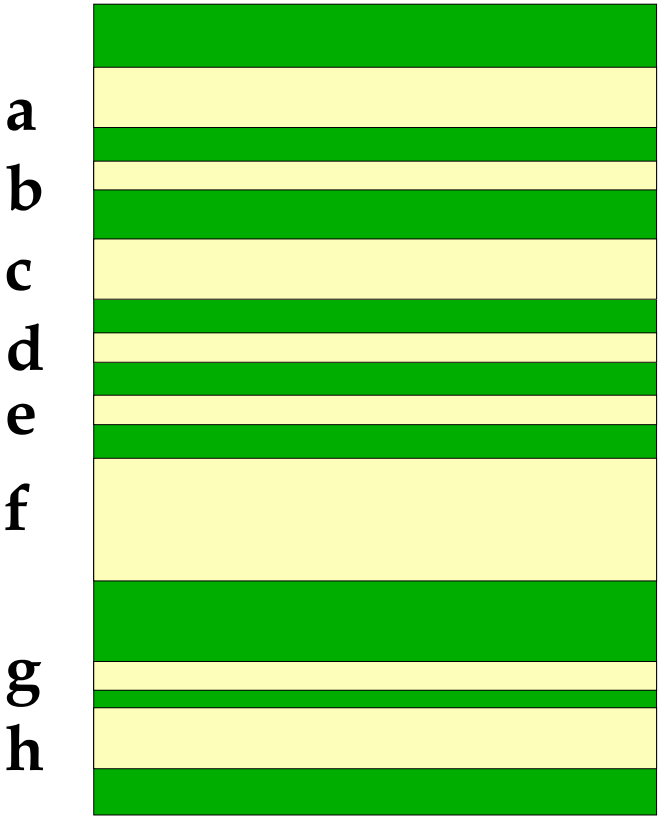


Net pay

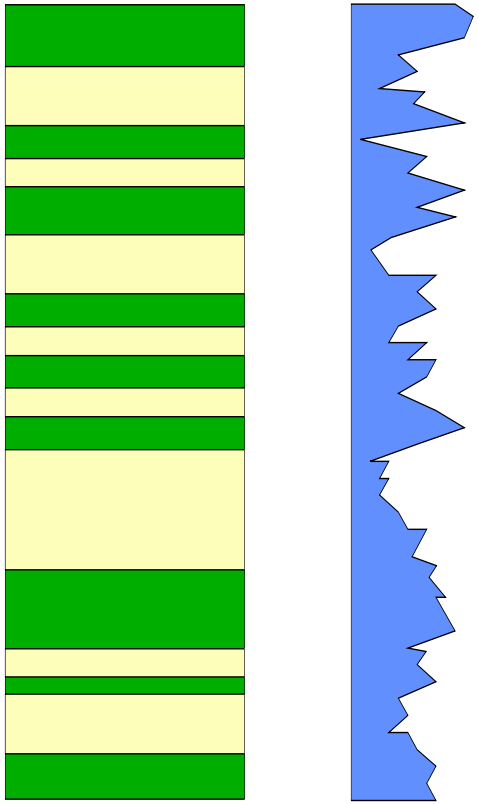
NET PAY =

The total thickness of all reservoir units (a-h) with

porosity > threshold value and permeability > threshold value



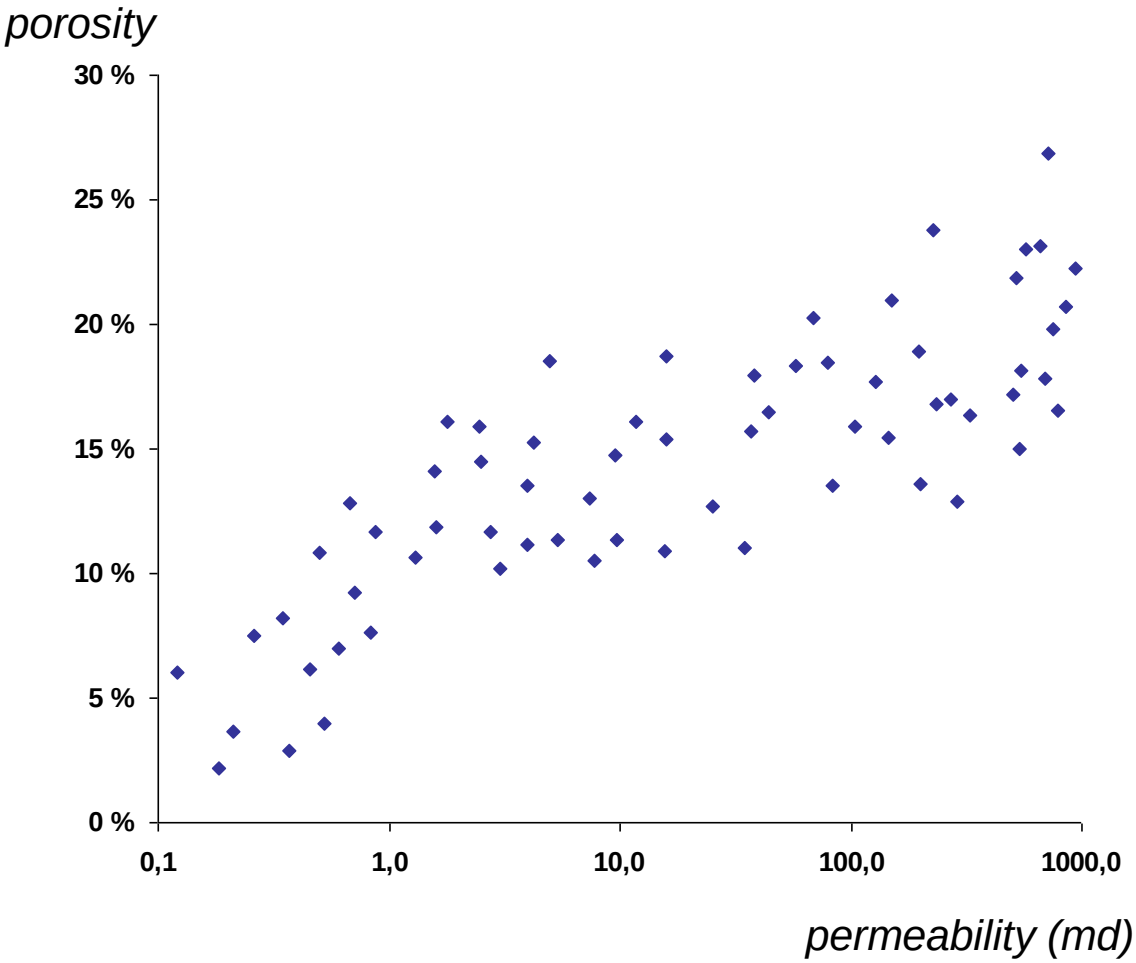
Porosity



- Calculated from electric well logs
- Core measurements

Average porosity larger than cut-off value

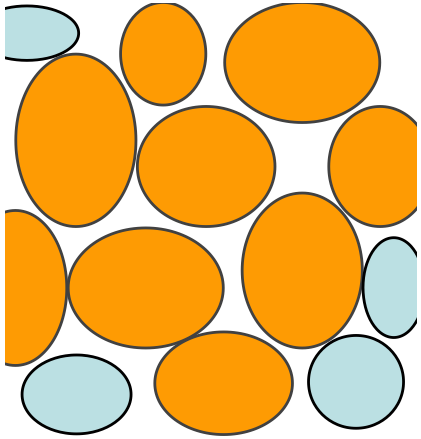
Poroperm plot



Measured porosities and permeabilities are plotted in a XY-diagram...

...in order to establish the cut-off value of efficient porosity

HC-saturation



Hydrocarbon saturation is the pore volume fraction which contains hydrocarbons

$$S_{HC} = 1 - S_{water}$$

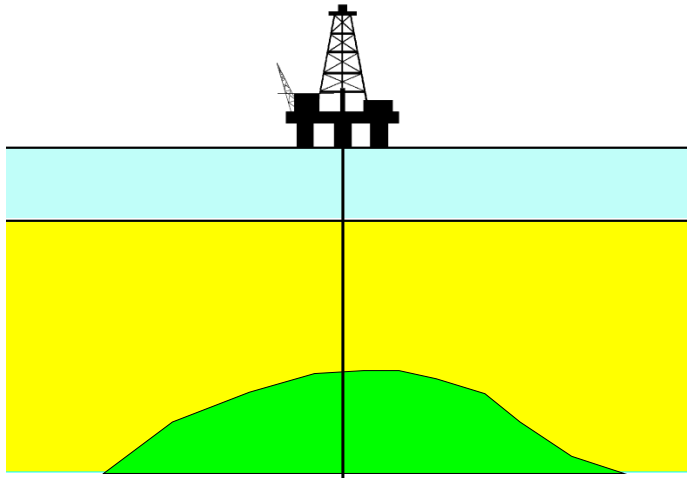
- **Hydrocarbon saturation (S_{HC}) is estimated from log analysis**
- **Only zones with efficient porosity are included**

Spread in input data

	min.	*expected*	*max.*
rock volume	*x*	*x*	*x*
net/gross ratio	*x*	*x*	*x*
porosity	*x*	*x*	*x*
hydrocarbon saturation	*x*	*x*	*x*

= Hydrocarbon pore volume (HCPV)

In-place resources

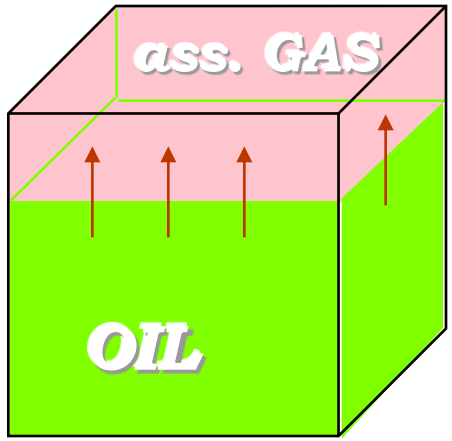


Surface conditions (p_0, T_0)

Reservoir conditions (p_R, T_R)

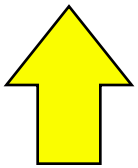
- **When we move hydrocarbons (HCPV) from the reservoir to the surface, physical conditions as pressure and temperature are changed...**
  - ***the oil volume is shrinking, and***
  - ***the gas volume is expanding***

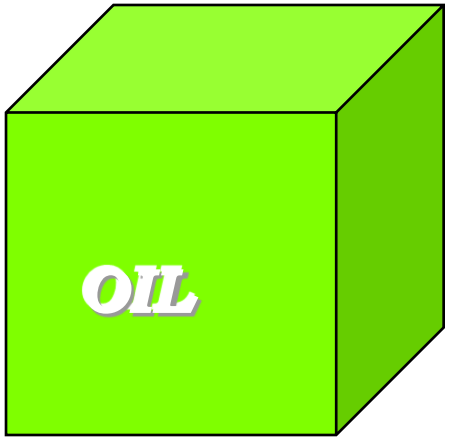
Oil to the surface...



Surface conditions

P (surface)
T (surface)
V (surface)





Reservoir conditions

P (reservoir)
T (reservoir)
V (reservoir)

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

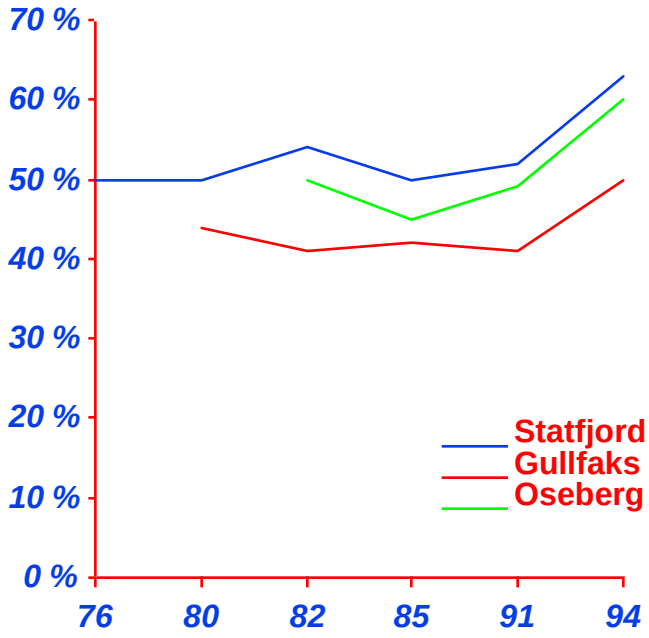
Recoverable resources =

In-place resources x recovery factor

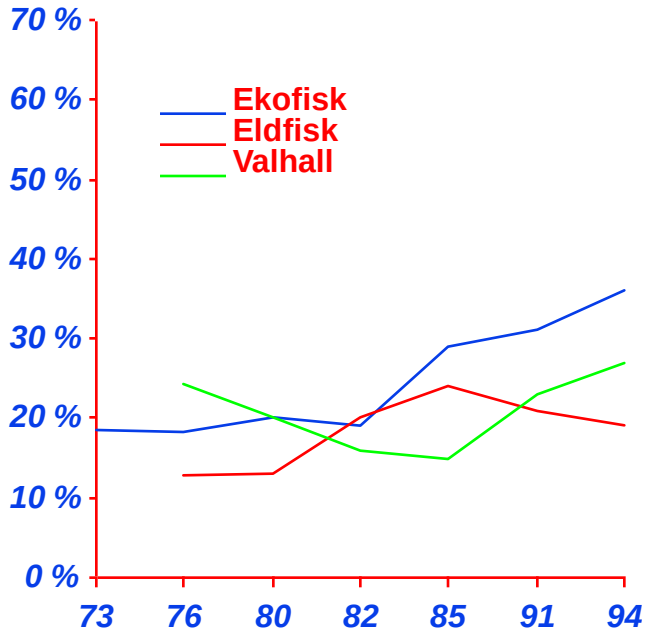
Depending on drive mechanisms and production strategy, the recovery factor in general varies:

- ***between 50 and 80 % for gas***
- ***between 25 and 70 % for oil***

Recovery factors for some Norwegian oil fields



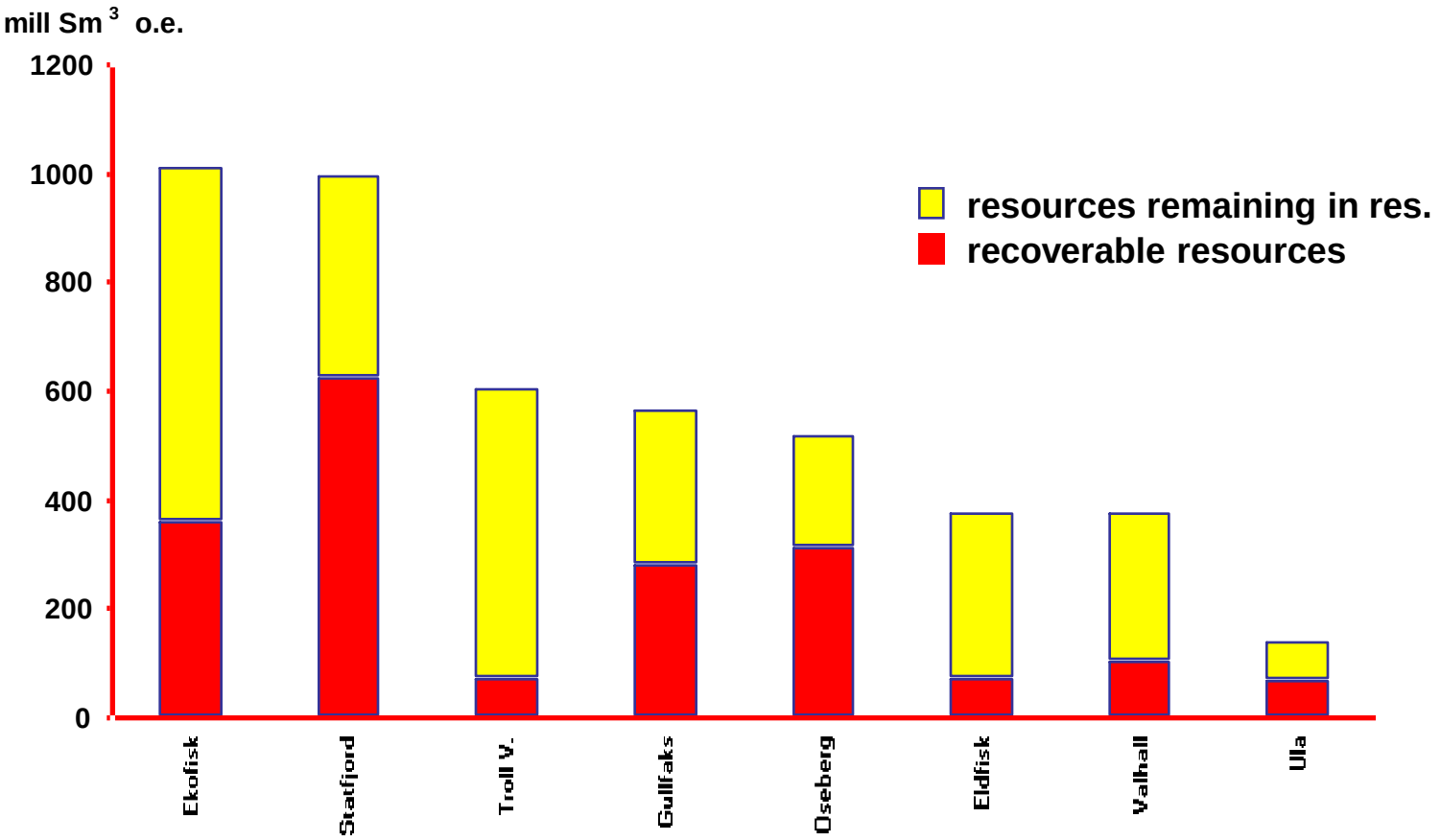
Middle Jurassic sandstones



Cretaceous chalk (carbonates)

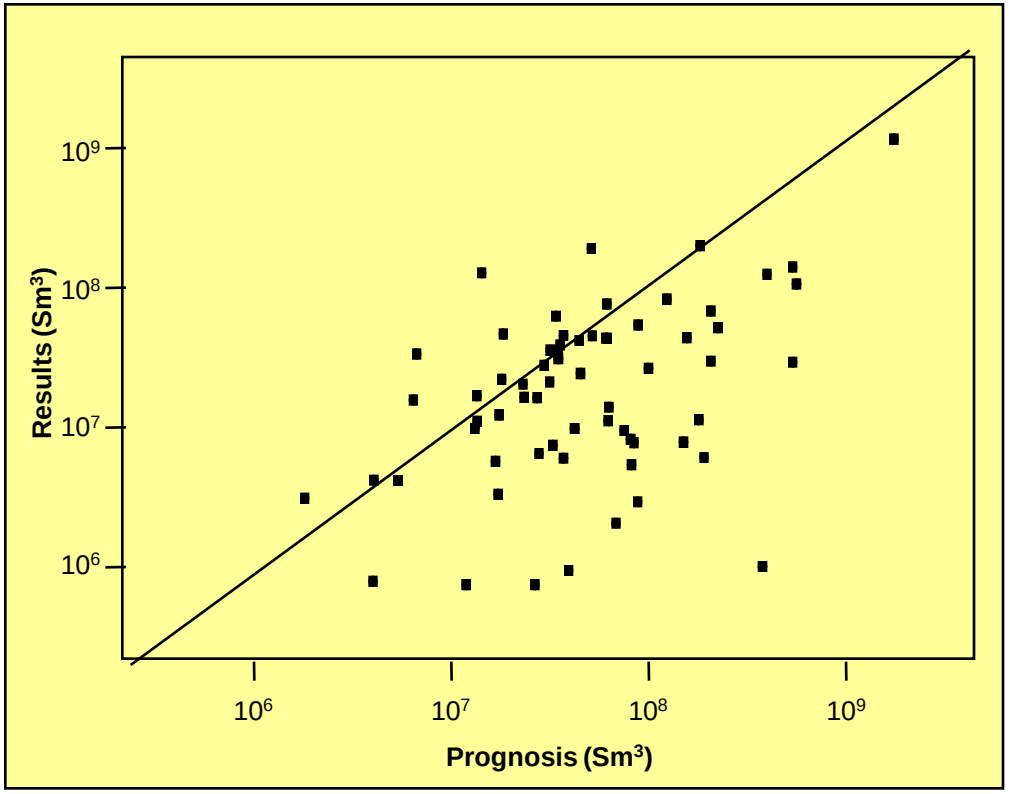
NPD

Recoverable and in-place resources

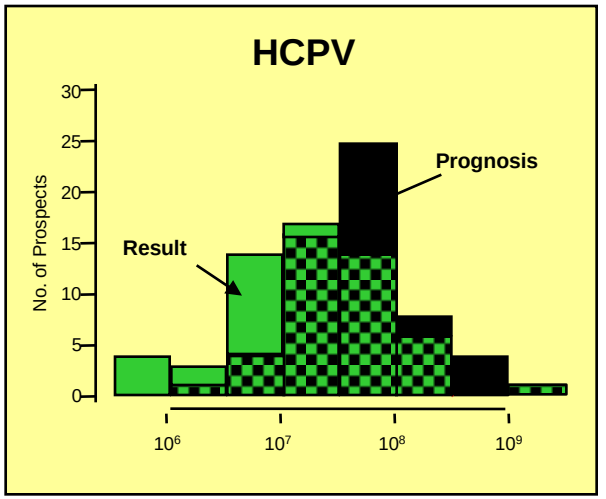


NPD

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

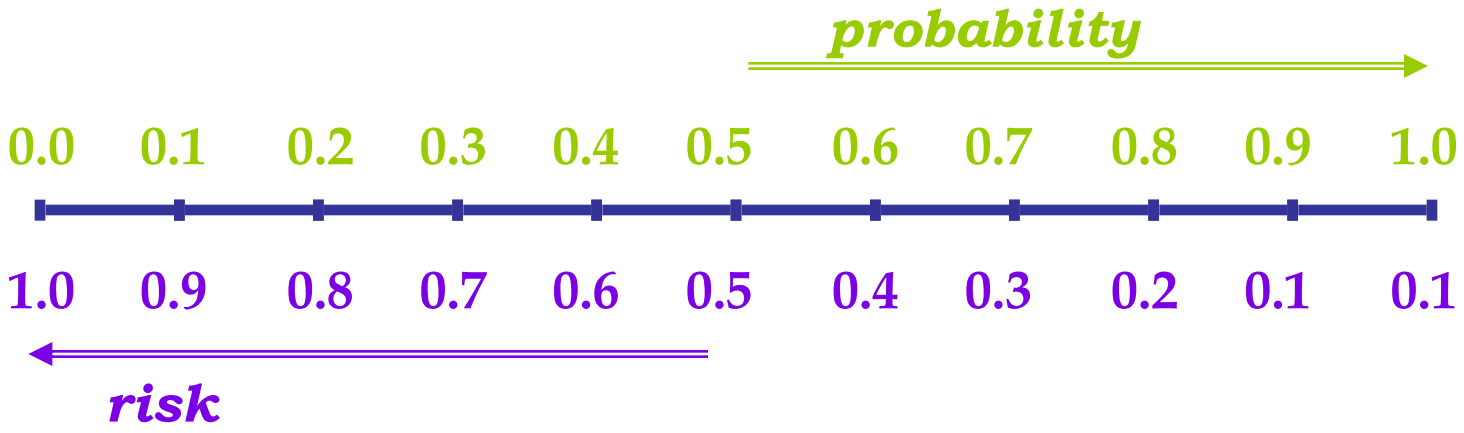
Risk analysis

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

Some Definitions

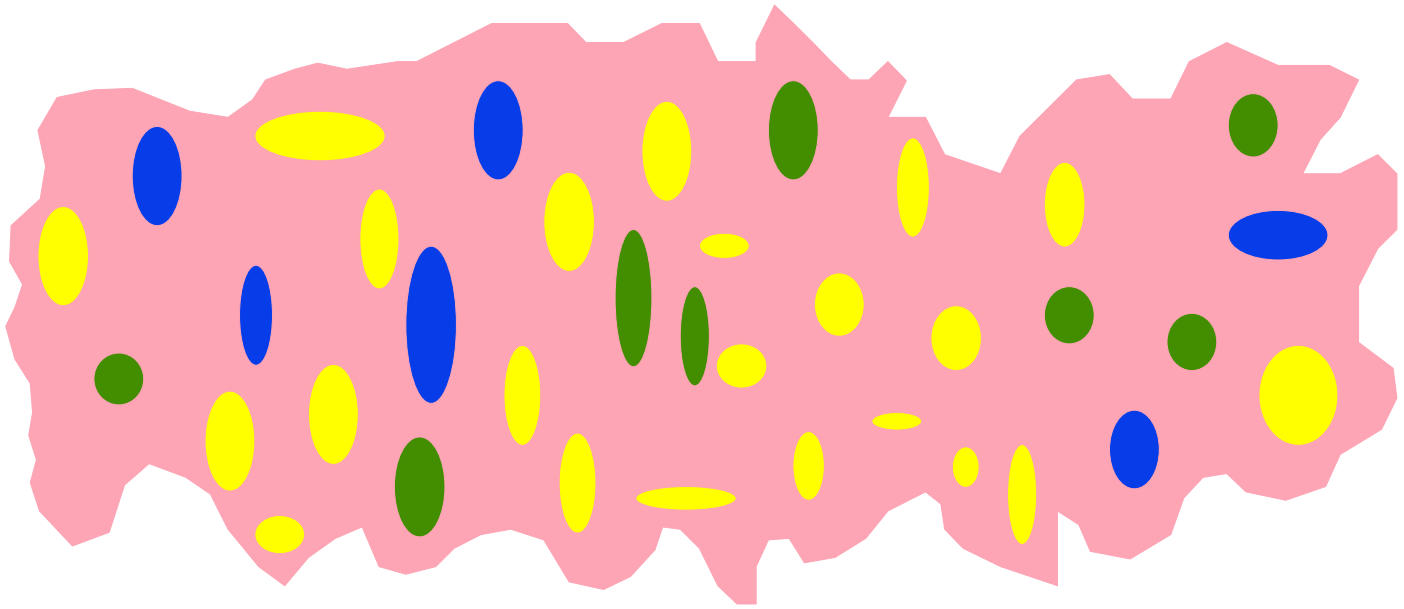
“There is a *RISK* that I am going to fall off this cliff and I am *UNCERTAIN* how far it is to the bottom!”

Risk - Probability



Probability = 1 - Risk

Success rate



$$\textit{Success rate} = \frac{\textit{no. of hits}}{\textit{no. of trials}} = 8/14 = 0.57$$

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:

$$P = P1 \times P2 \times P3 \times P4$$

...where:

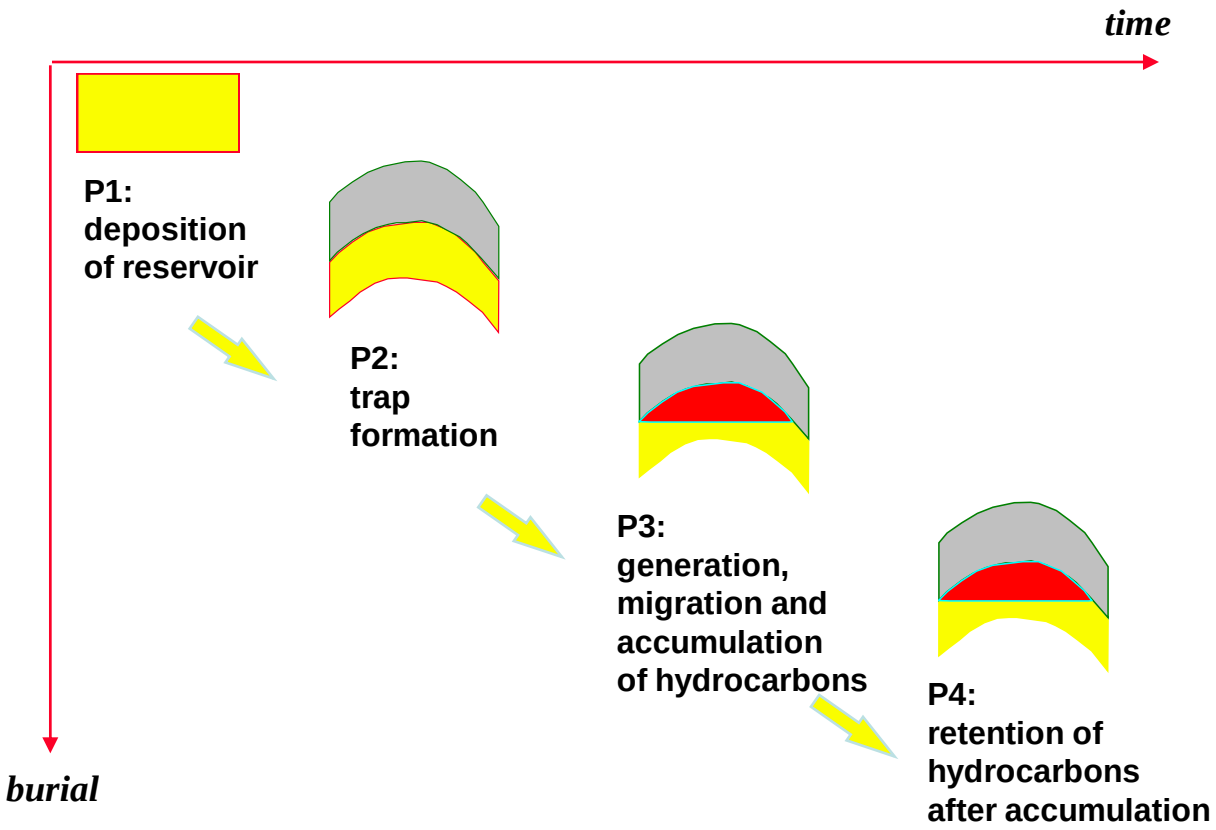
P1 - probability of efficient reservoir
P2 - probability of efficient trap
P3 - probability of efficient source & migration
P4 - probability of efficient retention after accumulation

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



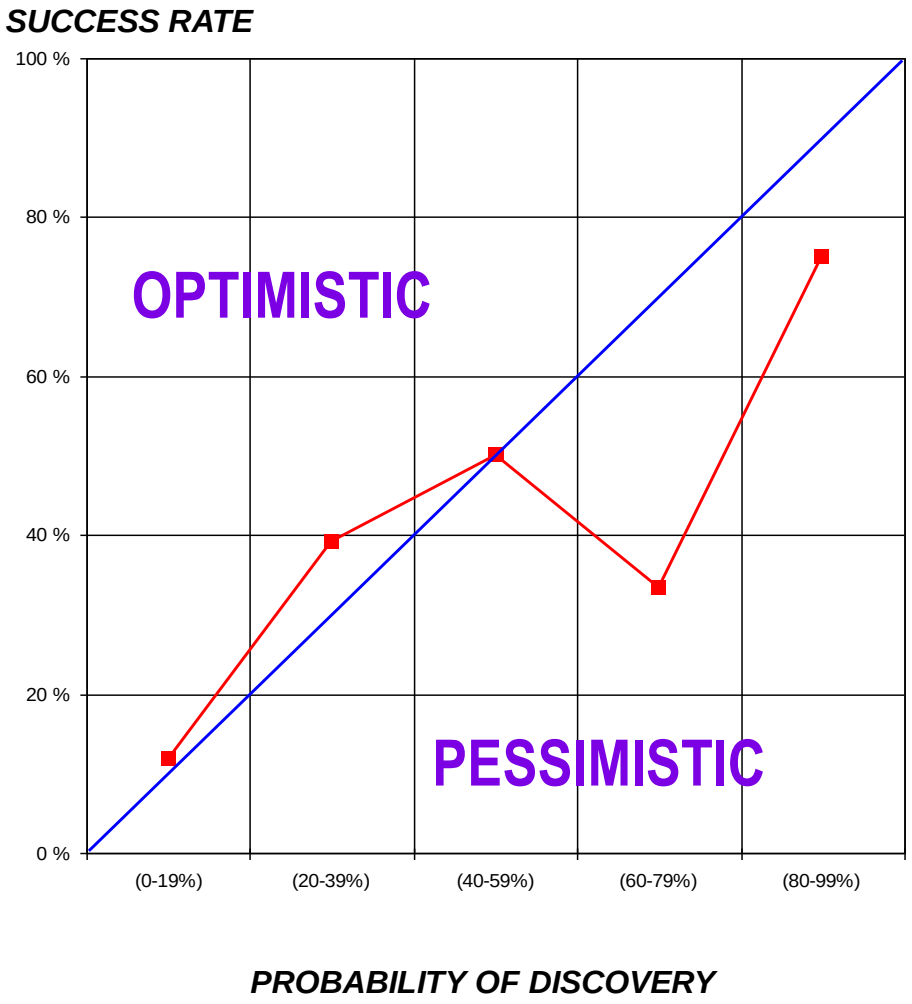
Sum up - Main principles

Independent risk factors for:

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

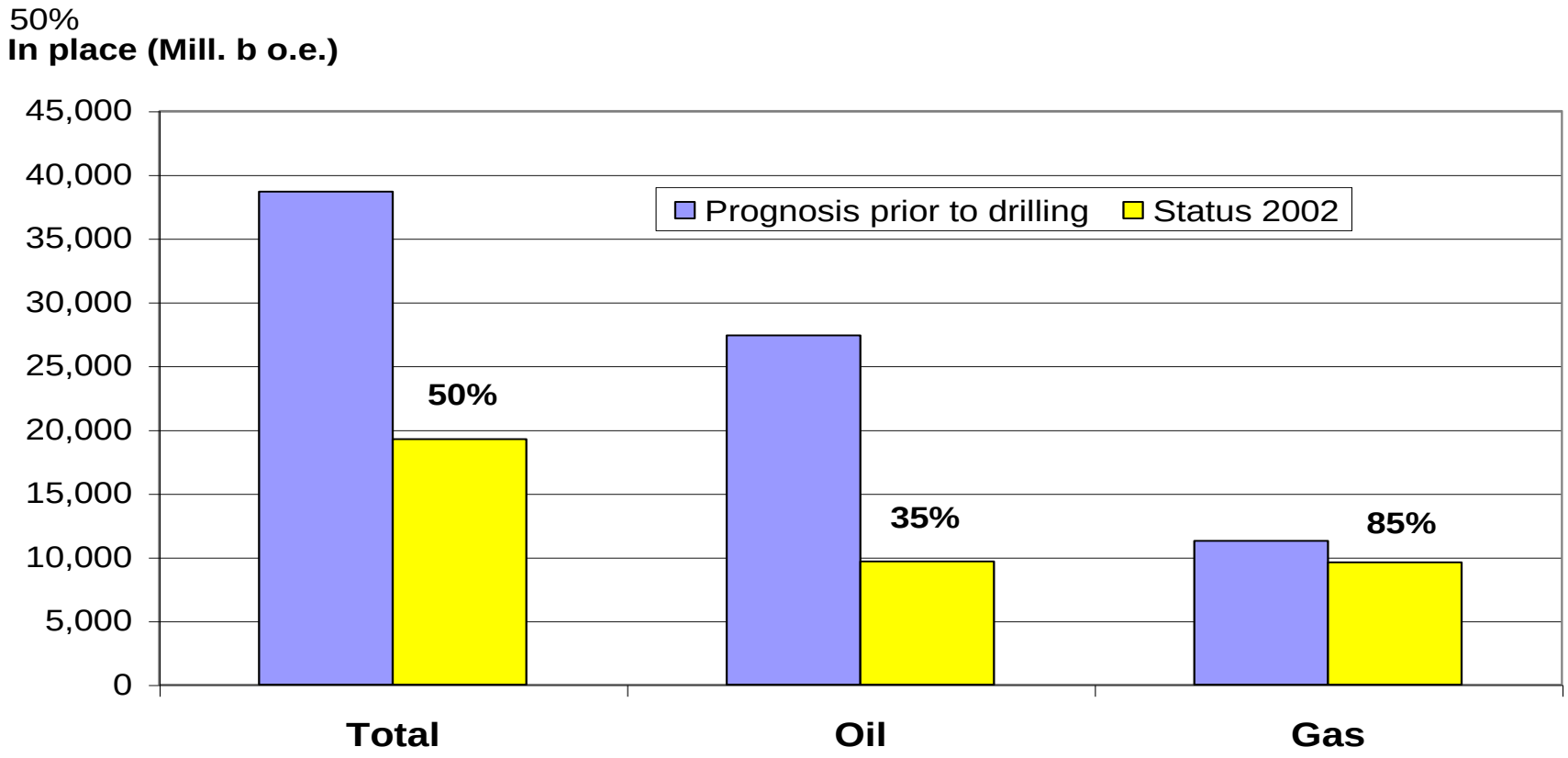
Probability of discovery

- 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



NPD