Managing portfolios of interdependent prospects:

an application to predicting future gas discoveries in the Netherlands

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Mini-symposium “Strategies for dealing with risk”, Wageningen, 13-01-'06
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CONTENT

• Future reserves estimation at TNO

• Incorporation of Spatial dependencies for large numbers (>10) of interdependent prospects

• Effects for (dutch gas) exploration Portfolios

Integrated Prospect Risk Analysis System (IPRAS)

- Five consecutive Phases
  - Generation
  - Migration
  - Trapping
  - Retention
  - Recovery

(original concept nederlof - shell)
Burial Graphs for High and Low
Petroleum history of Toarcian Source Rock in Low

Expelled Hydrocarbons (mg HC/g initial dry rock)

- Gas
- C6 +

Time (Ma)

Seal
Reservoir
Source
dTR/dt +20%
dExp/dt +20%
IPRAS

- Generation Phase
- Source Rock
  - bulk volume
  - composition
    - organic content
    - rock type
  - burial history
    - pressure
    - temperature

MATURITY WINDOWS GEOHISTORY

Vitrinite

0.6% 0.9% 1.2% 2.0%

Toarcian
IPRAS

- Migration Phase
  - Horizontal + Vertical migration distance
  - Rock type of migration path
  - Occurrence of faults / leaking seals
IPRAS

- Trapping Phase
  - Trap geometry
  - Trap timing
IPRAS

- Retention Phase
- Differential pressure across caprock
- Rock type of caprock
IPRAS

- Recovery phase
  - HydroCarbon properties
  - Production drive mechanism
    - natural depletion
    - water drive
    - compaction drive
- Rock type
- Well type / pattern
Reserves classification

- Produced + remaining
- Firm Futures
- Potential Futures in proven plays
- Potential Futures in non-proven plays
- Potential Futures in hypothetical plays

Increasing uncertainty
Firm Futures: prospects in proved play concept

- Rotliegend play, best known example of gas play in the Netherlands;
- Carboniferous,
- Zechstein, carbonate reservoirs
- Triassic,
- Jurassic-Cretaceous
- Chalk
- Tertiary (shallow gas)
Rotliegend Play-concept
Rotliegend play Map: Source
Rotliegend play map: Reservoir

Effect van paleorelief op dikte
Rotliegend play kaart: Seal

Limits of zechstein salt?
Rotliegend play map: Reservoir quality

Sand interfingering with silverpit sst
Rotliegend play map: Reservoir quality

Inverted area containing illite cementation, reducing porosity and permeability.
Rotliegend play map:

How certain is northern boundary
Reservoir property maps (porosity)
Gas composition 1

N2 Surface from Gas_sam_3_10_2

0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 60
60 - 70
70 - 75
75 - 80
No Data
Gas composition 2

Legend

Stratigraphic interpretation
- Fleurier
- Froidegand Volcanic
- Oligocene-Holocene
- Oligocene-Holocene
- Neogene-Holocene
- Early-Middle Eocene
- Early-Middle Eocene
- Oligocene-Holocene
- Oligocene-Holocene

Surrounding rocks
- Parti/Parti granite
- Cretaceous granite
- Eocene granite
- Early-Middle Eocene granite
- Oligocene-Holocene granite
- Oligocene-Holocene granite

Magmatic intrusion grid
- 200 - 499
- 400 - 499
- 500 - 699
- 600 - 799
- 700 - 899
- 800 - 999
- 1000 - 1199
- 1200 - 1399
- 1400 - 1599
- 1600 - 1799
- 1800 - 1999
- 2000 - 2199
- 2200 - 2399
- 2400 - 2599
- 2600 - 2799
- 2800 - 2999
- 3000 - 3199
- 3200 - 3399
- 3400 - 3599
- 3600 - 3799
- 3800 - 3999
- 4000 - 4199
- 4200 - 4399
- 4400 - 4599
- 4600 - 4799
- 4800 - 4999
- 5000 - 5199
- 5200 - 5399
- 5400 - 5599
- 5600 - 5799
- 5800 - 5999
- 6000 - 6199
- 6200 - 6399
- 6400 - 6599
- 6600 - 6799
- 6800 - 6999
- 7000 - 7199
- 7200 - 7399
- 7400 - 7599
- 7600 - 7799
- 7800 - 7999
- 8000 - 8199
- 8200 - 8399

CO2 Surface from Gas_sam_3_1

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Prospect administration

- location: x-y, license type, stream-area, operator
- Mean Success Volume of accumulated gas (MSV)
- Triangular distribution around MSV
- Possibility of Success (POS) for finding gas
- Distance to existing infrastructure
Portfolio Simulation (1), Yearly process in EXPLOSIM simulator

- MSV Prospect Ranking
  - Selected EMV > 0
  - EMV < 0
    - rejected

- Explore
  - Show (POS)
  - Dry (1-POS)

- VOL (appraisal) Production
  - NPVSucces
  - NPVSucces < 0
  - NPVSucces > 0

- Sub-economic

- produce

- NPV = NPVSucces

- NPV = 0
  - NPV = -drywellcost

- NPV = -drywellcost
Ranking of prospects (1) (EMV)

• Before Exploration

  • $EMV = POS^*\sim NPV_{success} - (1-POS)^*\text{drywellcost}$

  • $\sim NPV_{success} = A \times MSV^2 + B \times MSV + C$
Ranking of prospects (2) (EMV)
NPVSucces

- After successful Exploration (= appraisal of VOL)

  - NPVSucces = A * VOL^2 + B * VOL + C

- VOL = appraise volume (exploration)

- VOL from monte-carlo sampling
Example, single stream area 17 prospects
EXPLOSIM Version 0.02 Project: MyProject

Graph type: p90, p50, p10, mean

Parameters:
- Economic
- Technical
  - series_GAS_VOLUME[MLD]
  - series_GAS_OHV
  - series_GAS_WOEBE
  - series_GAS_N2
  - series_GAS_CO2
  - series_GAS_H2S

TNO 2005
Portfolio Volume

Risk vs Volume

Volume (Billion M³) vs Risk (Std Volume)

Parameters:
- VOLUME_CUM
- EXPLORED
- DRY
- SUBECON
- ECON
- CUMMY_EXPLORATION
- CUMPA_PRODUCTION
- tme_2004
- yGAS_VOLUME[MLD]_2004
- yGAS_GHV_2004
- yGAS_WOBBE_2004
- yGAS_N2_2004
- yGAS_CO2_2004
- yGAS_H2S_2004
- tme_2005
- yGAS_VOLUME[MLD]_2005
- yGAS_GHV_2005
- yGAS_WOBBE_2005
- yGAS_N2_2005
- yGAS_CO2_2005
- yGAS_H2S_2005
- tme_2006
- yGAS_VOLUME[MLD]_2006
- yGAS_GHV_2006
- yGAS_WOBBE_2006
- yGAS_N2_2006
- yGAS_CO2_2006
- yGAS_H2S_2006
- tme_2007
- yGAS_VOLUME[MLD]_2007
- yGAS_GHV_2007
Probability correlations

• Two prospects HC1 and HC2 in different fault blocks, fault side seal is critical for Prospect POS.

POS (HC1) = P(HC1) = 0.5

• Assumption is that if side seal is proved for HC1 it will increase the chance of finding HC2 else decrease.

POS (HC2) = P(HC2|HC1) = 0.7
1-POS (HC2) = P(_HC2|HC1) = 0.3

Sum is 1, For negative outcome of HC1 the same should be specified

POS (HC2) = P(HC2|_HC1) = 0.3
1-POS (HC2) = P(_HC2|_HC1) = 0.7
Incorporation of Prospect dependencies, using Bayesian Statistics

Dependent prospects with positive correlation:

\[ P(\_HC2|\_HC1) = 0.7 \]
\[ P(HC2|HC1) = 0.3 \]

\[ P(\_HC2|HC1) = 0.3 \]
\[ P(HC2|HC1) = 0.7 \]
Incorporation of Prospect dependencies, using Bayesian Statistics

- Evaluate NPV higher in the tree
- Find Value of Information of \((I1) = 2\)
Incorporation of Spatial dependencies, using Bayesian Belief networks for many prospects

- Conditional probabilities requires calculation of joint probabilities
  - \( P(A|B,C,..) = \frac{P(A,B,C,..)}{P(B,C,..)} \)

- Calculation routine:
  - \( NS=100000 \) MC samples of normal distribution for each prospect
  - Correlate samples with correlation matrix (strength of correlation is dependent on distance)
  - \( POS = P(A) = \frac{\#(\text{samples } A > \text{treshold})}{NS} \)
  - Evaluate \( P(A,B,C,..) \) as \( \frac{\#(\text{samples } A > \text{treshold}, \text{samples } B > \text{treshold}, \text{..})}{NS} \)

- for many prospects (>5) solution breaks down
  Use most relevant connections
Portfolio NPV (effect of exploration costs)

- No dependency POS
- Dependency POS

Risk (sd NPV) vs. NPV

- 10MLN$
- 30MLN$
- 50MLN$
- 70MLN$
Conclusions

• Spatial dependencies between prospects can increase significantly the risk of portfolios in terms of volume and NPV

• Using bayesian updating of POS in ranking of prospects can reduce risk significantly.

• At high Exploration cost, “risked NPV” can be higher for dependent prospects than for non dependent prospects

• Therefore, underestimating the inter-prospect dependency can lead to a significant loss of upside resource potential.