Polskie Górnictwo Naftowe i Gazownictwo SA

Classification for Gas Reserves applicable in Poland

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Reserves Classification ranked by the degree of exploration

In Poland, Minister of the Enviroment's Resolution (Journal of Laws No 136, item 1151 of 6 July 2006) is defining the exploration categories for oil & gas reservoirs, which are required by the Geological Report.

According to Section 5.1 of the above Resolution the following three categories of exploration: C, B &A are determined for natural gas, crude oil & methane from hard coal reservoirs.

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Category C

boundaries of reservoir estimated as a result of geophysical research & geological interpretation.

The data obtained are used to continue more detailed exploration works or field development after obtaining a hydrocarbons inflow of commercial interest from AT LEAST ONE WELL

The most important for category C is that: The range of statistical estimation of average reservoir features and reserves MUST NOT EXCEED 40%

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Category B

The geological model of the reservoir is quite good and correct to define its boundaries (shape, size, structure of hydrocarbon trap) and to estimate reservoir parameters with theirs vertical / horizontal variance.

Category B is based on results of the detailed exploration.

The most important for Category B is that:
The range of statistical estimation of avarage reservoir features and reserves MUST NOT EXCEED 30%

Category A

requirements as for Category B but complying with PRODUCTION DATA from oil/gas field exploitation.

The most important for Category A is that:
The range of statistical estimation of avarage reservoir features and reserves MUST NOT EXCEED 15%

Basic methods of reserves estimation

- volumetric
- material balance
- production decline curves analysis
- statistical

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Volumetric – basic method mainly used at the general & detailed reservoir exploration stage

$$Q = A \cdot \overline{HNET} \cdot \overline{PHIE} \cdot \overline{SG} \cdot \frac{1}{B_g}$$

- Q - original gas in place (geological reserves)
- A – reservoir surface
- HNET– average effective thickness
- PHIE – average effective porosity
- SG – average gas saturation
- B_g – gas formation volume factor

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Multiplication of reservoir parameters maps:

- Effective porosity – PHIE
- Net/gross thickness - HNET
- Gas saturation – SG

$$Q = \frac{1}{B_g} \cdot \sum a_i \cdot q_i$$

- Q = original gas in place
- a_i – surface of every map cell
- q_i – hydrocarbon pore thickness in every map cell

  $q_i = PHIE_i * HNET_i * SG_i$
- B_g – gas formation volume factor

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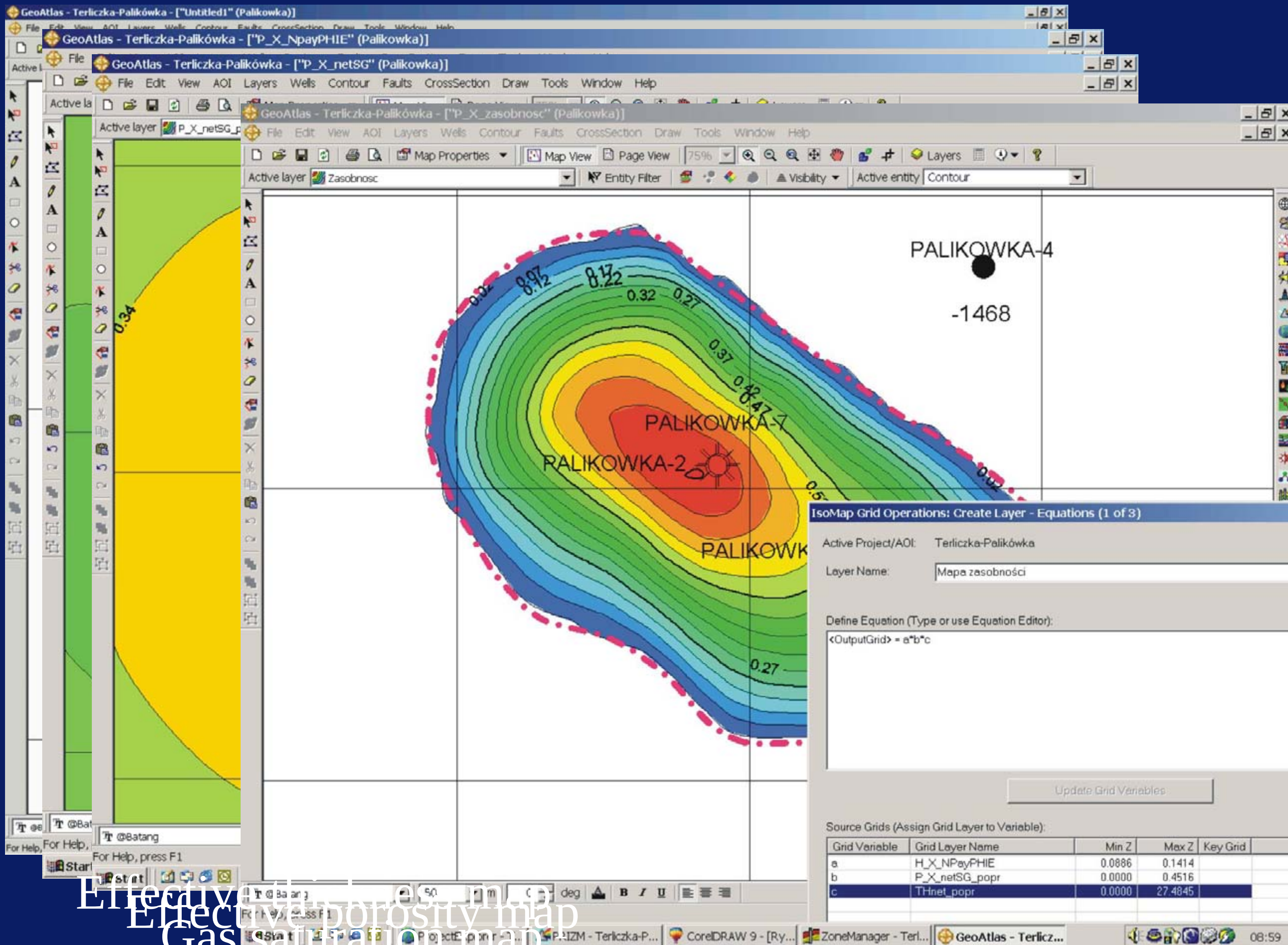

Effective th[illegible] map

Effective porosity map

Gas saturation map

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Hydrocarbon pore thickness map

Material Balance – dynamic method
is used only at the reservoir exploitation stage

Gas material balance equations:

$$F = GE_{tot} + US(P,t)B_w = G(E_g + E_{fw}) + W_e B_w$$

- F - Total production (withdrawal) gas or gas & water
- G – Original gas in place
- E_{tot}– Total expansion of reservoir $E_{tot} = E_g + E_{fw}$
- E_g – Expansion of gas
- E_{fw} – Expansion of connate water and reduction in the pore volume
- U – Aquifer constant
- S(P,t)– Aquifer function (depending on model, pressure and time)
- W_e - Cumulative natural water influx
- B_w – Expansion of water

The four most popular graphic solutions of gas material balance equations

- P/Z method
- Havlena - Odeh method
- Cole method
- Pressure Math method

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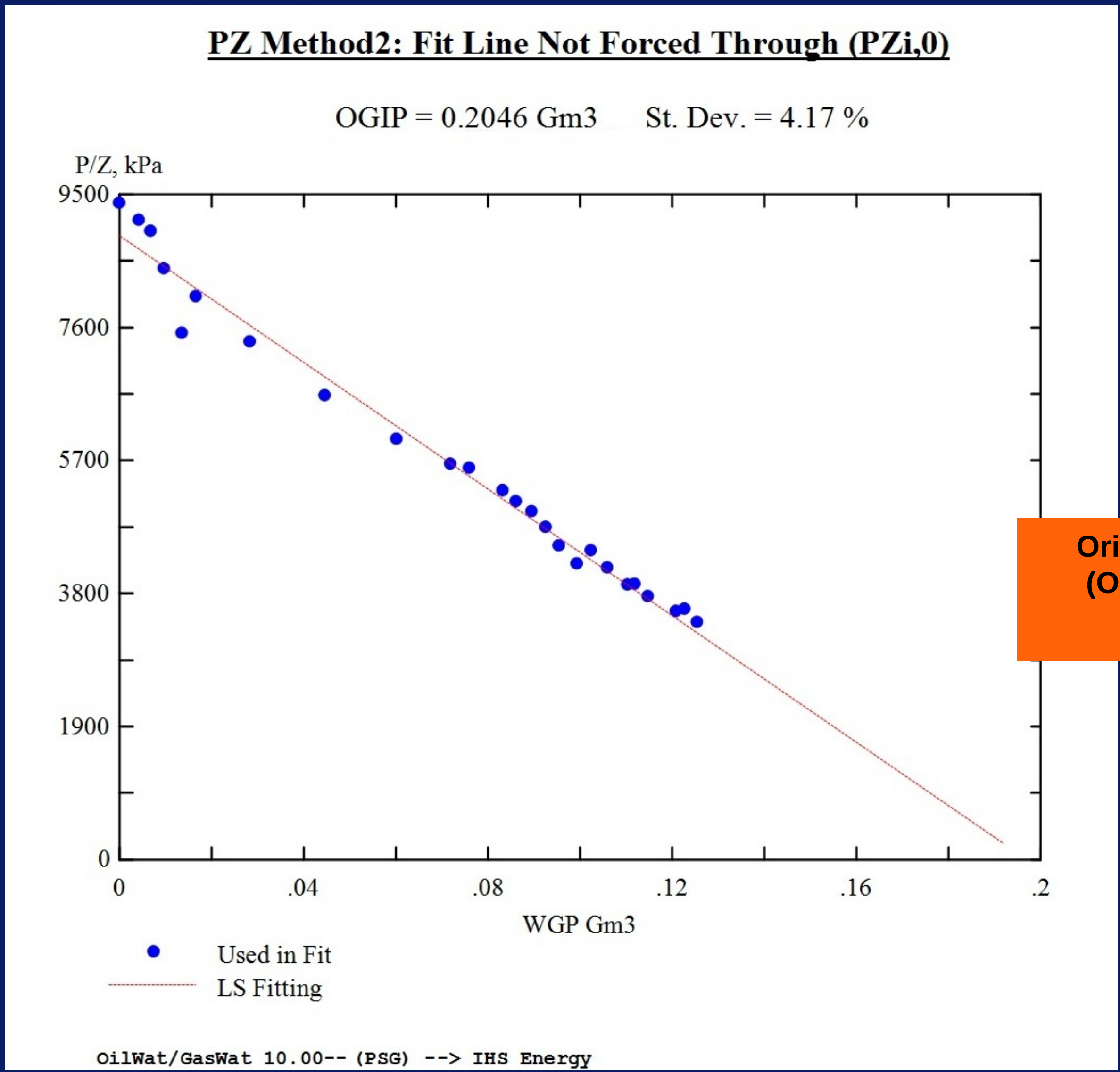
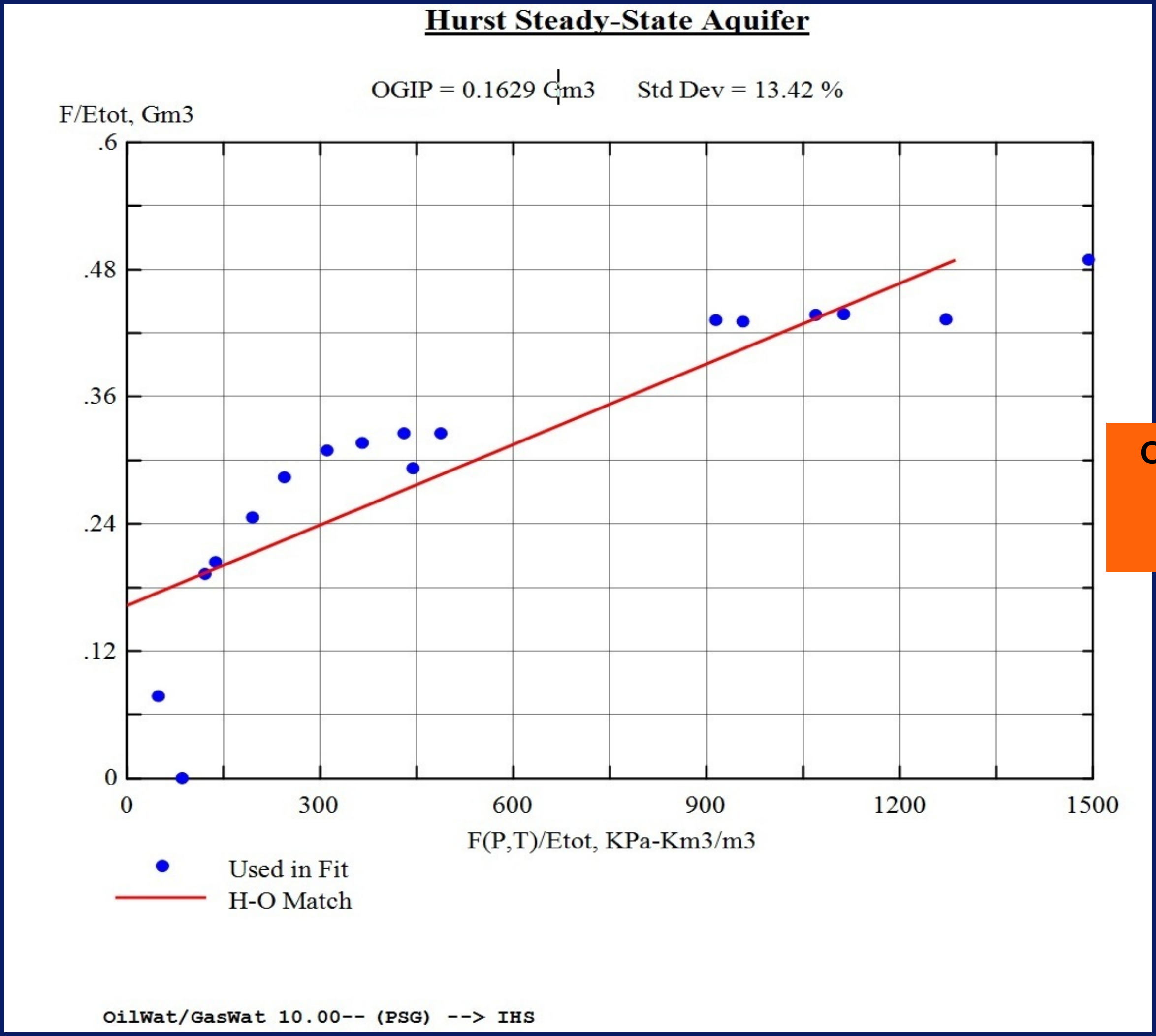
P/Z method – Pressure / Z- factor vs Cumulative Gas Production



Original Gas in Place (OGIP) = 200 mln nm^3 = 7,2 BCF

Havlena – Odeh method for gas reservoir with water influx



Original Gas in Place (OGIP) = 160 mln nm^3 = 5,6 BCF

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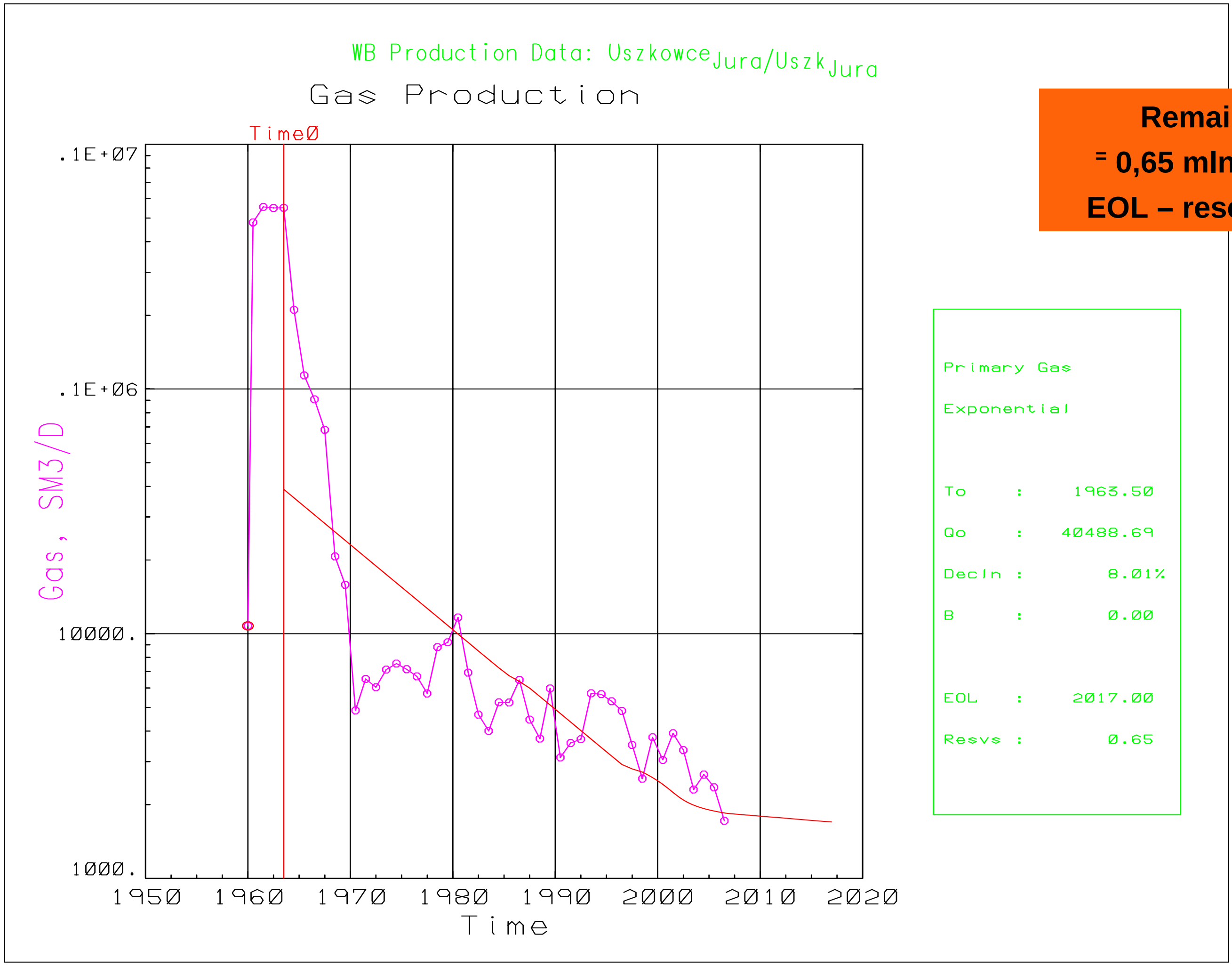
Production decline curve analysis – successful dynamic method



Remainig reserves
= 0,65 mln nm3 = 0,2 BCF
EOL – reservoir end of life

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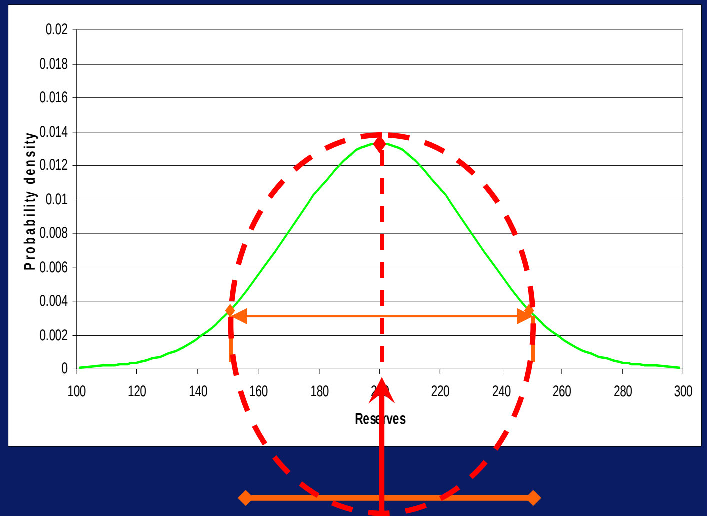
Range of reserves estimation

- Many wells (>20) in the reservoir

$$P(\overline{Q} - z_{\frac{\alpha}{2}} \cdot \frac{s}{\sqrt{n}} < Q < \overline{Q} + z_{\frac{\alpha}{2}} \cdot \frac{s}{\sqrt{n}} s) = 1 - \alpha$$



Q reserves expected value

$\overline{Q}$ reserves average value (based on well data)

s reserves standard deviation (based on well data)

z confidence factor from Gaussian distribution

n number of wells

α significance level (**1-**α – confidence level; **1-**α =0.9)

range of expected reserves value

P=0.9

reserves expected value $\pm z_{\frac{\alpha}{2}} \cdot \frac{s}{\sqrt{n}}$

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- several wells (4-20) in the reservoir

$$P(\overline{Q} - t_{\frac{\alpha}{2}} \cdot \frac{s}{\sqrt{n-1}} < Q < \overline{Q} + t_{\frac{\alpha}{2}} \cdot \frac{s}{\sqrt{n-1}}) = 1 - \alpha$$

Q reserves expected value

$\overline{Q}$ reserves average value (based on well data)

s reserves standard deviation (based on well data)

t confidence factor from t-Student distribution

n number of wells

α significance level (**1-**α – confidence level; **1-**α =0.9)

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1-3 wells – Monte Carlo simulation

- Assumption of data intervals and type of data distribution for independent reservoir parameters:
  - surface A
  - effective thickness THNET
  - effective porosity PHIE
  - gas saturation coefficient SG
- Values sampling – random sampling from defined above data populations of every parameter – many, many times
- „reserves” population set up – every reserves value calculated from set of sampled data

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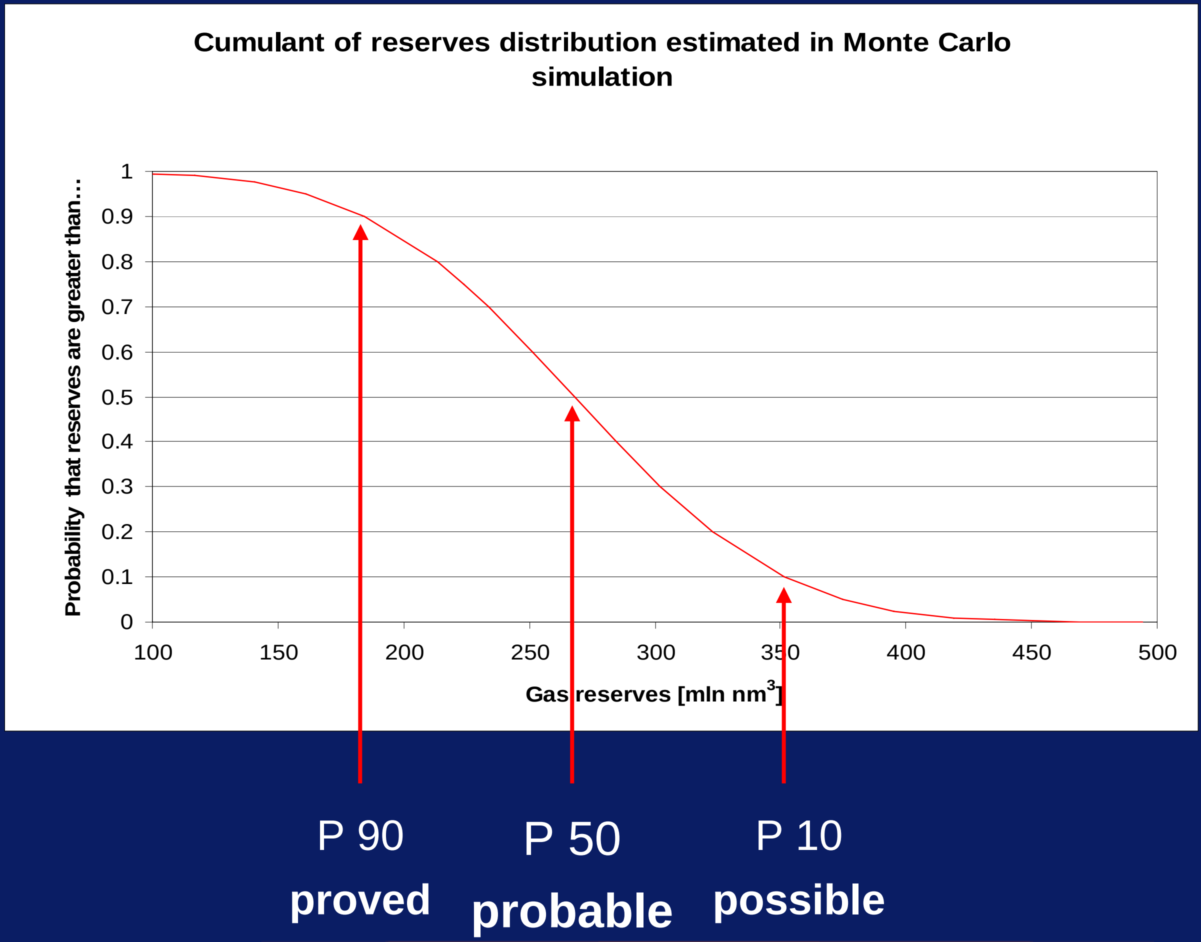
- Reserves expected value estimation based on statictical parameters of „sampled reserves" population

$$P(\overline{Q} - z_{\frac{\alpha}{2}} \cdot s < Q < \overline{Q} + z_{\frac{\alpha}{2}} \cdot s) = 1 - \alpha$$



Thank you for your attention !