How much is in the tank? Reservoir volume uncertainty

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Motivation

- Reserves are a major component of an energy company's value
- Estimating reserves accurately is essential

Objective

- Make a **prediction** of the oil volume as well as its **likelihood**

Standard techniques used in resource/reserve estimation

- SPE/WPC/AAPG/SPEE – Petroleum Resources Management System (PRMS) – 2007

“Incorporation of seismic analysis typically improves the underlying reservoir models and yields more reliable resources estimates.”

- SEC approved new reporting rules (effective January 1st, 2010)

The Volumetric Method

Hydrocarbon in place

Oil reservoirs

$$OOIP = \frac{7{,}758 \times A \times h \times \phi \times (1 - S_{wi})}{B_{oi}}$$

OOIP = Original oil in place

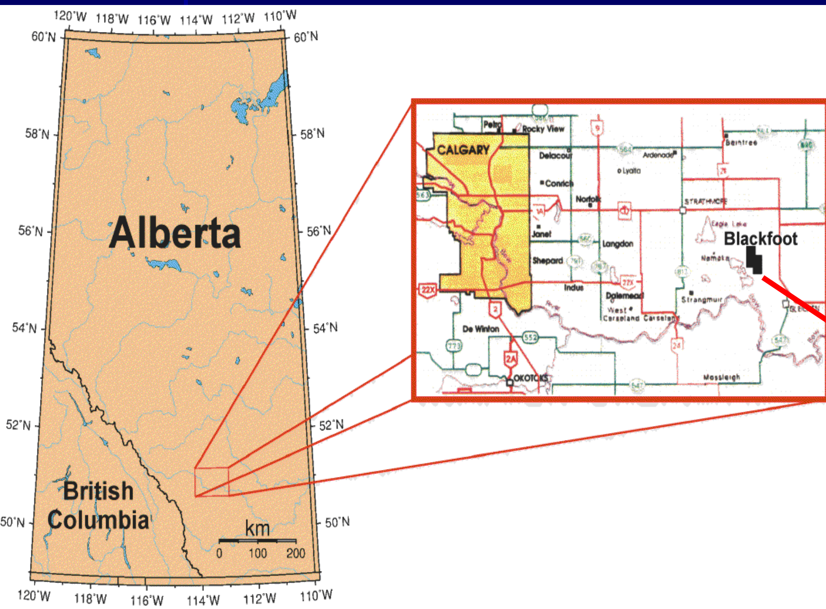
Our focus

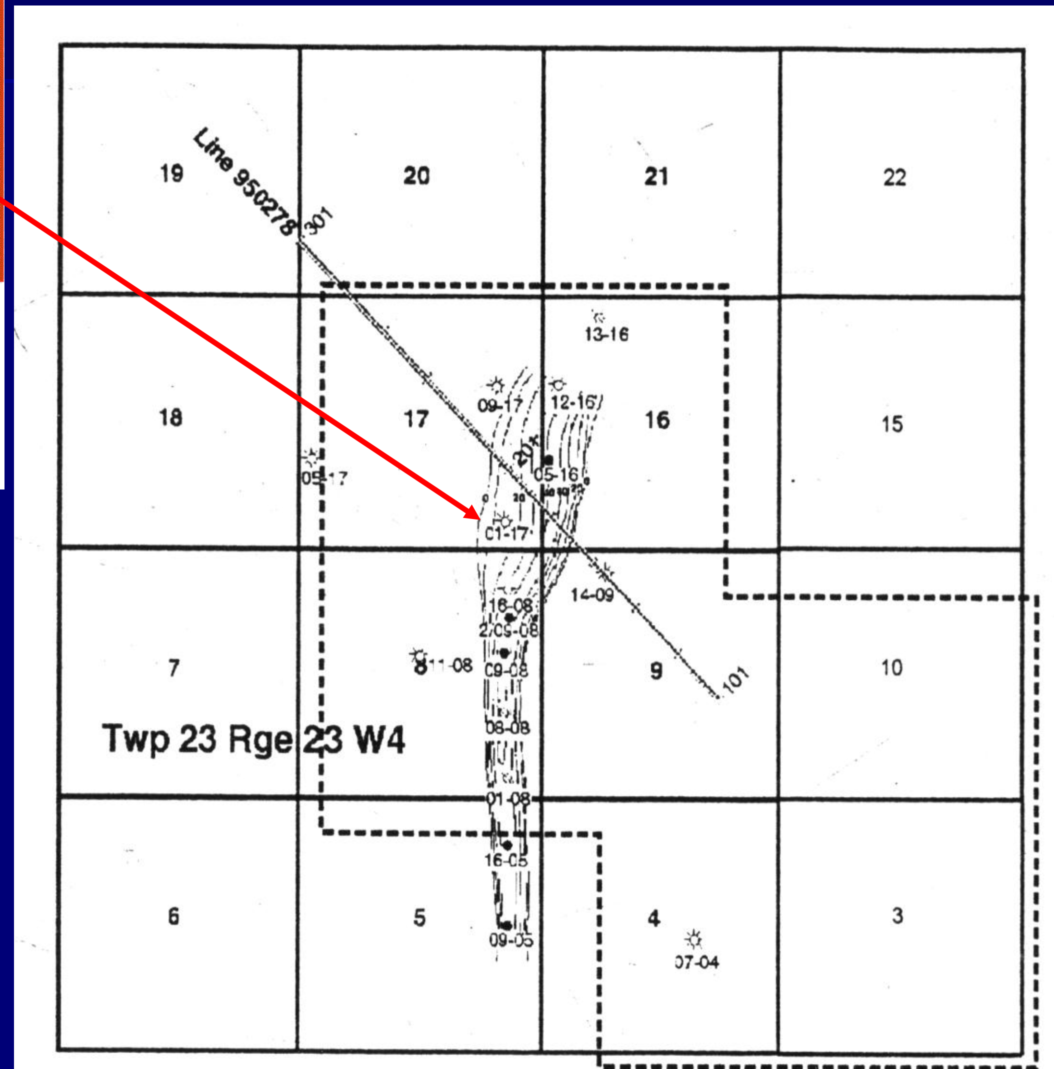
- A = Area (acres)
- h = net pay thicknesss (ft)
- ϕ = porosity (fraction)
- S_{wi} = initial water saturation (fraction)

B_{oi} = initial oil formation volume factor (rb/stb)

Tearpock, 2011

Blackfoot 3C-3D: location map





Todorov 2000

HC reservoirs are found in structural and stratigraphic traps where porous **channel sands** pinch out against non-reservoir regional strata or low-porosity sediments.

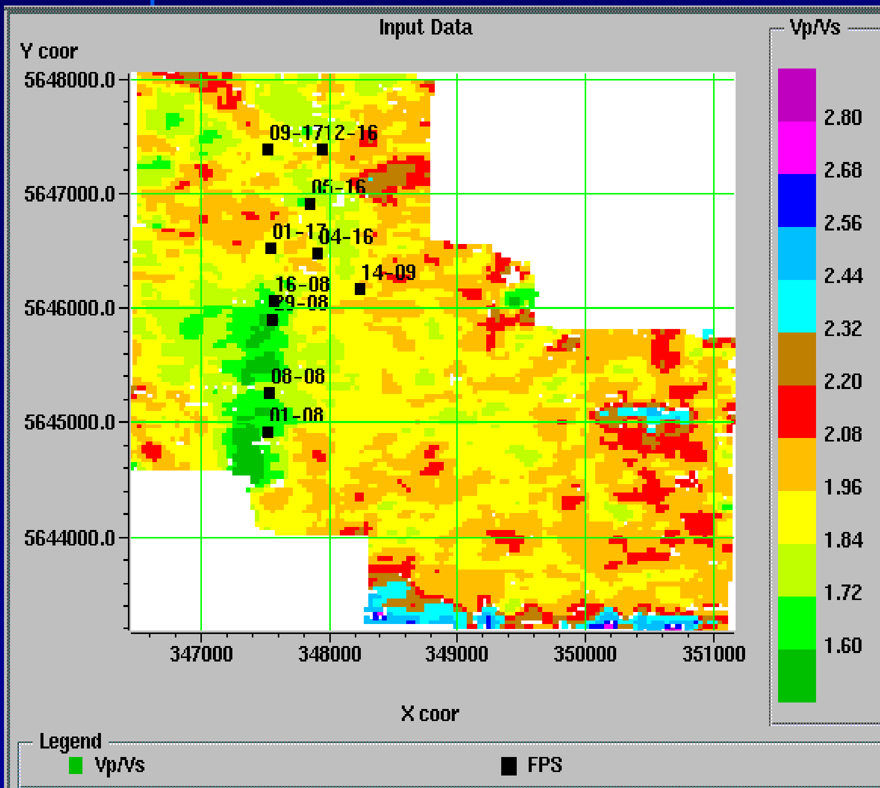
Primary HC at the field is oil, although some gas may be encountered.

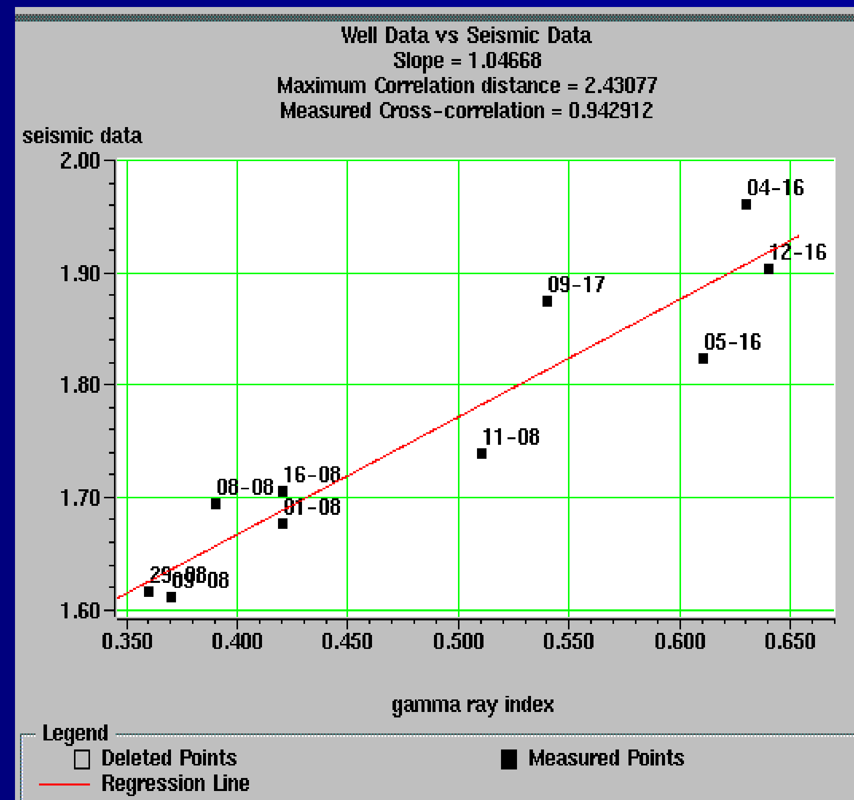
Spreading the GRI information

Vp/Vs distribution

Vp/Vs vs GRI

From 3C-3D seismic data



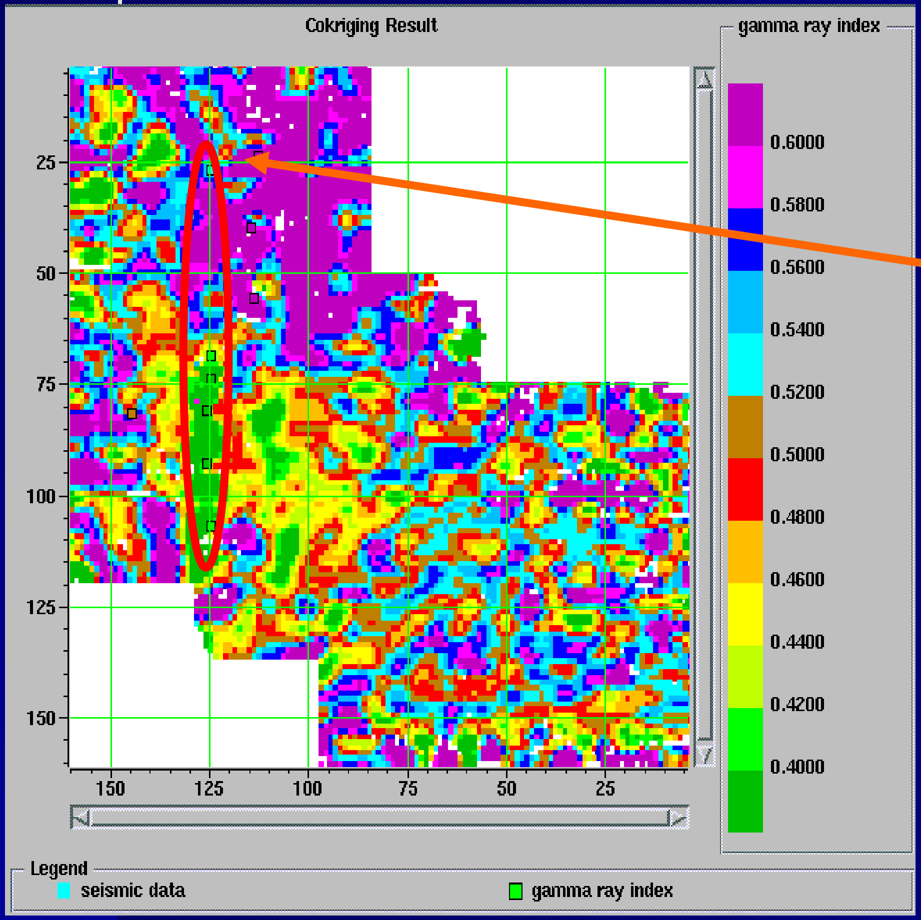


correlation: 0.94

Todorov & Stewart, 2000

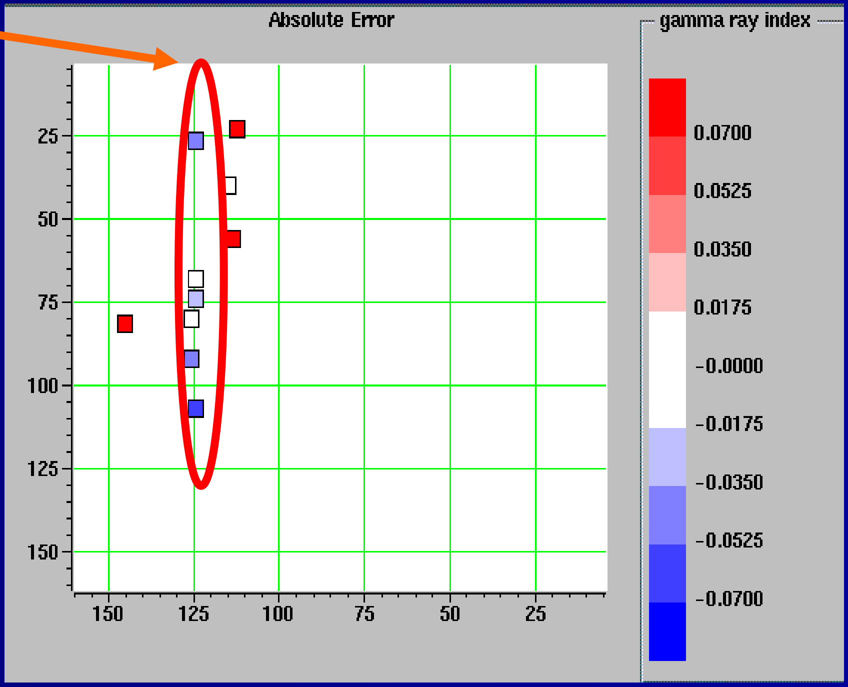
Uncertainty in GRI cokriging

GRI after cokriging



Cross-validation

Absolute error



Todorov & Stewart, 2000

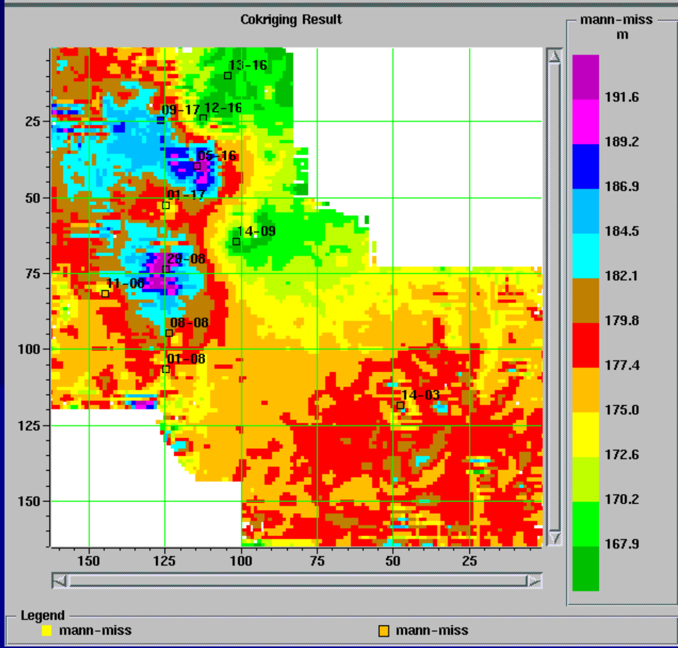
Area of the reservoir

OV = Area * OC

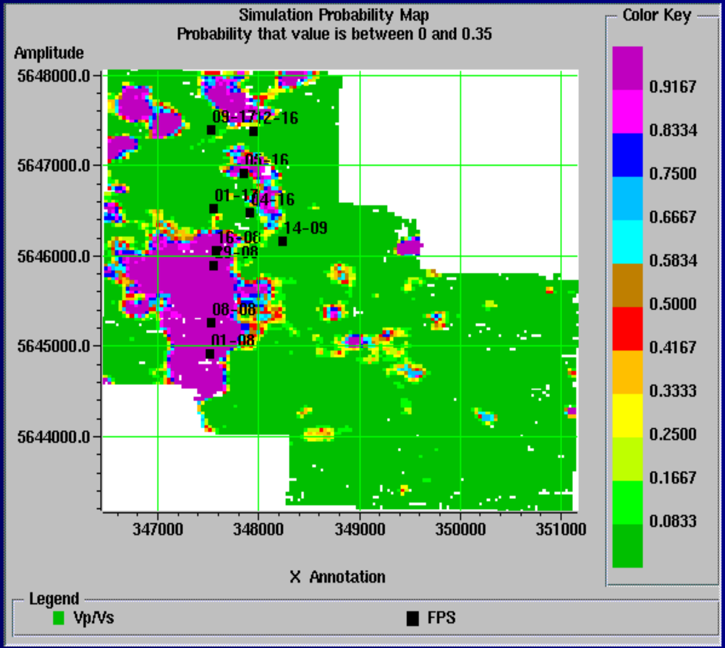
Area should be defined by (Ringrose 2007):

- **V-shale cut off (net sand)**
- **Porosity cut-off (net reservoir)**
- **Saturation cut-off (net pay)**

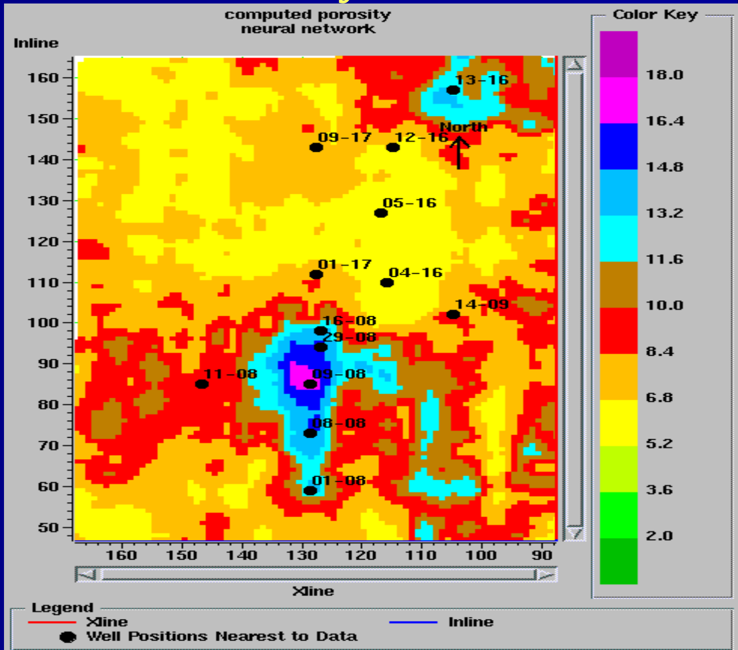
Thickness distribution



Sand distribution



Porosity distribution



PCP Engineering

Drain. area = 64 Ht

Net Pay = 17.5m

OOIP ~ 1.36x10^{6}m^3

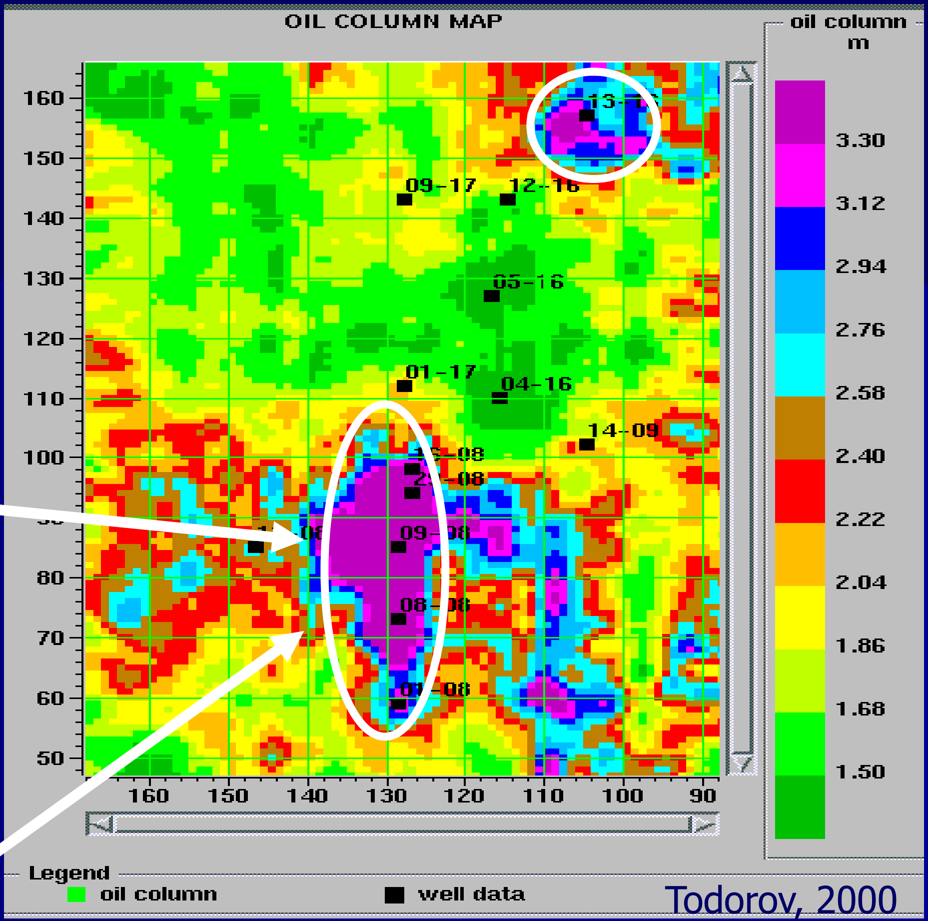
Seismic & Logs

Area ~ 60 Ht

Oil column ~ 3m

Volume ~ 1.2x10^{6}m^3

Stewart 2010 ⊕ **Sw = 0.25**



<u>Oil volume</u> predicted by Todorov

$OV_{Todorov}$ ≈ 7,910,000 bbl

1st Method of estimation of uncertainty in OV

Uncertainty/Error quantification → Comparison of a measured/simulated value with a *reference value*

Blind wells procedure (cross-validation)
+
Well log data (reference value)

} independent measurements

% Error thickness = 6%

% Error %sand = 10%

% Error porosity = 11%

Adopting that the measurements and errors are independent to each other, using σ as a measurement of the uncertainty

Uncertainty in OV

(Coleman & Steele, 1989)

$$\left(\frac{\sigma_{OV}}{OV}\right)^2 = \left(\frac{\sigma_{thickness}}{thickness}\right)^2 + \left(\frac{\sigma_{\%sand}}{\%sand}\right)^2 + \left(\frac{\sigma_{\phi}}{\phi}\right)^2 + \left(\frac{\sigma_{S_{HC}}}{S_{HC}}\right)^2 + \left(\frac{\sigma_{Area}}{Area}\right)^2$$

% Error thickness = 6%

% Error %sand = 10%

% Error porosity = 11%

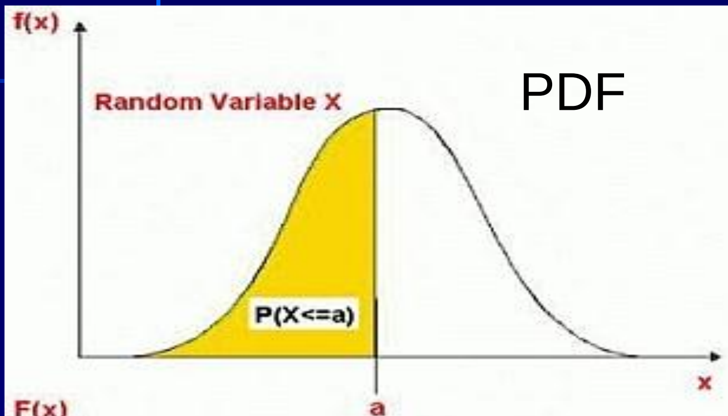
% Error S_{oil} (from logs) = 10%

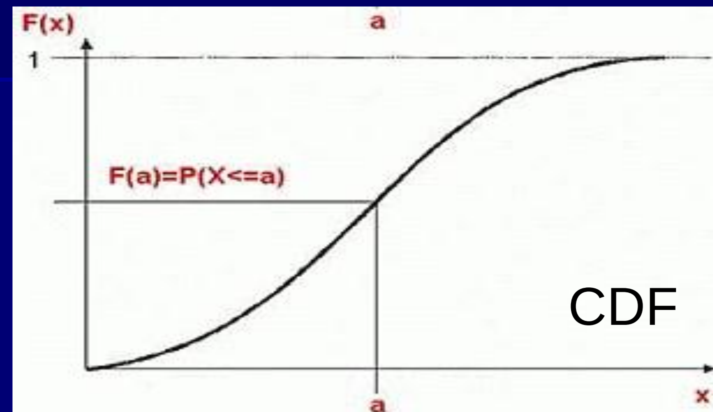
% Error Area = 15%

$$\frac{\sigma_{ov}}{ov} \cong 0.23$$

Uncertainty in the Oil Volume

Exploring the PDF-CDF relationship





$$\frac{\sigma_{ov}}{ov} \cong 0.23$$

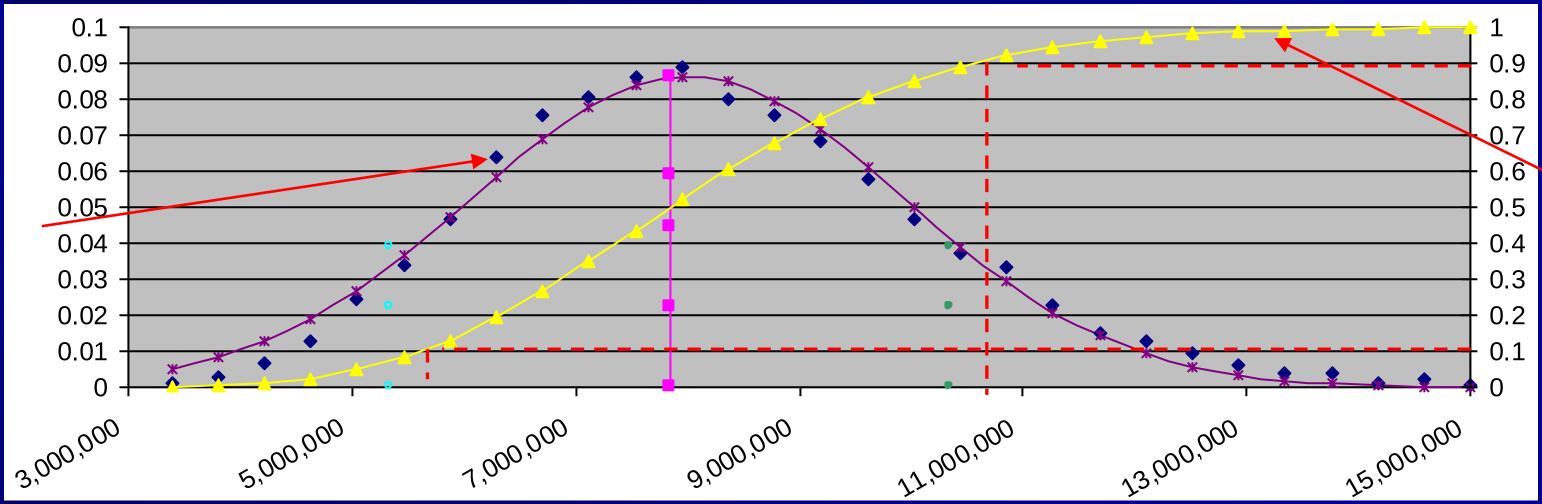
$$P_{90} = 0.706 \times OV_{Todorov} \approx 5{,}585{,}000 \text{ bbl}$$

$$P_{10} = 1.294 \times OV_{Todorov} \approx 10{,}235{,}000 \text{ bbl}$$

Monte Carlo approach

- $OV = thickness \times \%sand \times \phi \times (1 - S_{wi}) \times$ Area
- 10,000 simulations

PDF



CDF

bbl

P_{90} = 5,700,000 bbl

P_{10} = 10,612,000 bbl

Conclusions & Future work

- A total uncertainty was associated with the OV prediction

- A probability was associated with the OV prediction

- Quantification of the contribution of geophysical information used in the OV prediction should be done

  - **Picking uncertainty**

$$t_e = \frac{1}{f_m \log_2\left[1 + \left(\frac{S}{N}\right)^2\right]}$$

Stewart et al. 1984

$$SSE(f) = SS(f)\sqrt{SD \cdot NR \cdot NA}$$

Meunier, 2011