Luca Fava

# Structural Uncertainty Evaluation

# Gross Rock Volume (GRV)

$$\mathrm{HIIP} = \frac{\mathbf{GRV}*N{:}G*\Phi*(1-S_w)}{\mathrm{FVF}}$$

**Gross Rock Volume is the most significant factor in estimating in-place hydrocarbons**

We cannot measure directly GRV, only infer it from other measurements

We have no samples of the trap pre-drill (Quirk, Technical forum)

We can be sure our map before drilling an exploration prospect is not entirely correct (10% - 1% chance the trap is bigger than closure model), (Quirk, Technical forum)

# Gross Rock Volume (GRV) Uncertainties

- **Pick Uncertainty**
  - correlation of pick to geology (well tie/phase)
  - change of impedance laterally causing pick position to change
  - picking accuracy/smoothing by interpreter
- **Contouring Uncertainty**
  - 2D seismic does not define minima/maxima
  - 3D seismic may be smoothed
  - choice of algorithm
- **Depth Conversion Uncertainty**
  - Velocity model selection
  - Incorporating Stacking Velocity (STKV) data

    STKV are inaccurate (imprecise and biased) without any calibration, but densely sampled.

    They can constrain a lateral trend.

    Often (especially in frontier exploration areas) STKV are the only source of information.

**GRV uncertainty can be estimated using GEOSTATISTICAL realisations (stochastic simulation) of Depth Conversion > unbiased evaluation**

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# Geostatistical Approach (1)

This approach is routinely used in Resource assessment by some of the major companies (such as Eni) through proprietary softwares internally developed.

Some Service Company (such as Earth Works) offers either their expertise in this methodology or their dedicated softwares.

It is possible to use the same approach using **Petrel**.

Can be used to estimate GRV in **(1)** prospects**, (2)** appraisal well planning and **(3)** fields

1) No wells
2) Isoprobability map (one control point)
3) Control points (wells)

# Geostatistical Approach (2)

- Krige well velocities (where available) with stacking velocities

- Create multiple velocity map **realisations** (tied to wells);

- Combine with time map to create multiple (isoprobable) depth **realisations** and calculate resulting GRV's;

- Create cumulative GRV probability plot for input to resource assessment



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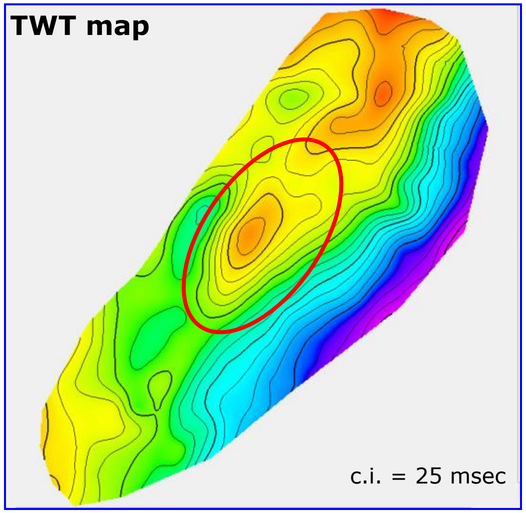
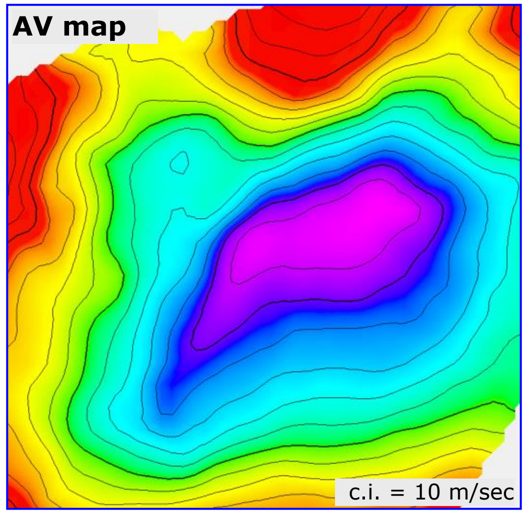
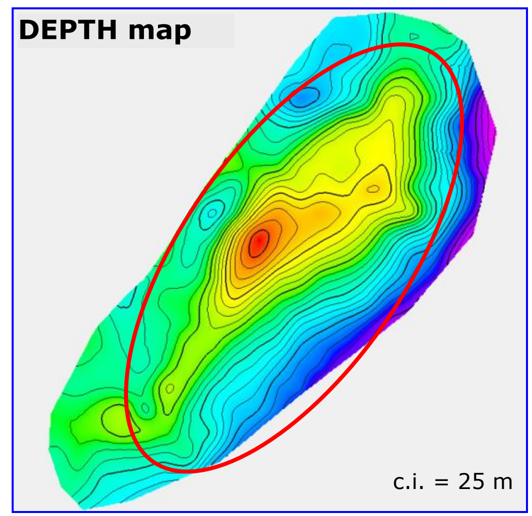
# Structural Uncertainty (GRV) Evaluation




Even if a proper velocity approach is chosen and the best depth image is obtained, still there is significant uncertainty associated with the velocity field, that can have a huge impact on the volumes




**The velocity model can have a big impact on the area of the closure and thus on volumetrics. It is crucial then to evaluate the Uncertainty related to the Depth Conversion.**

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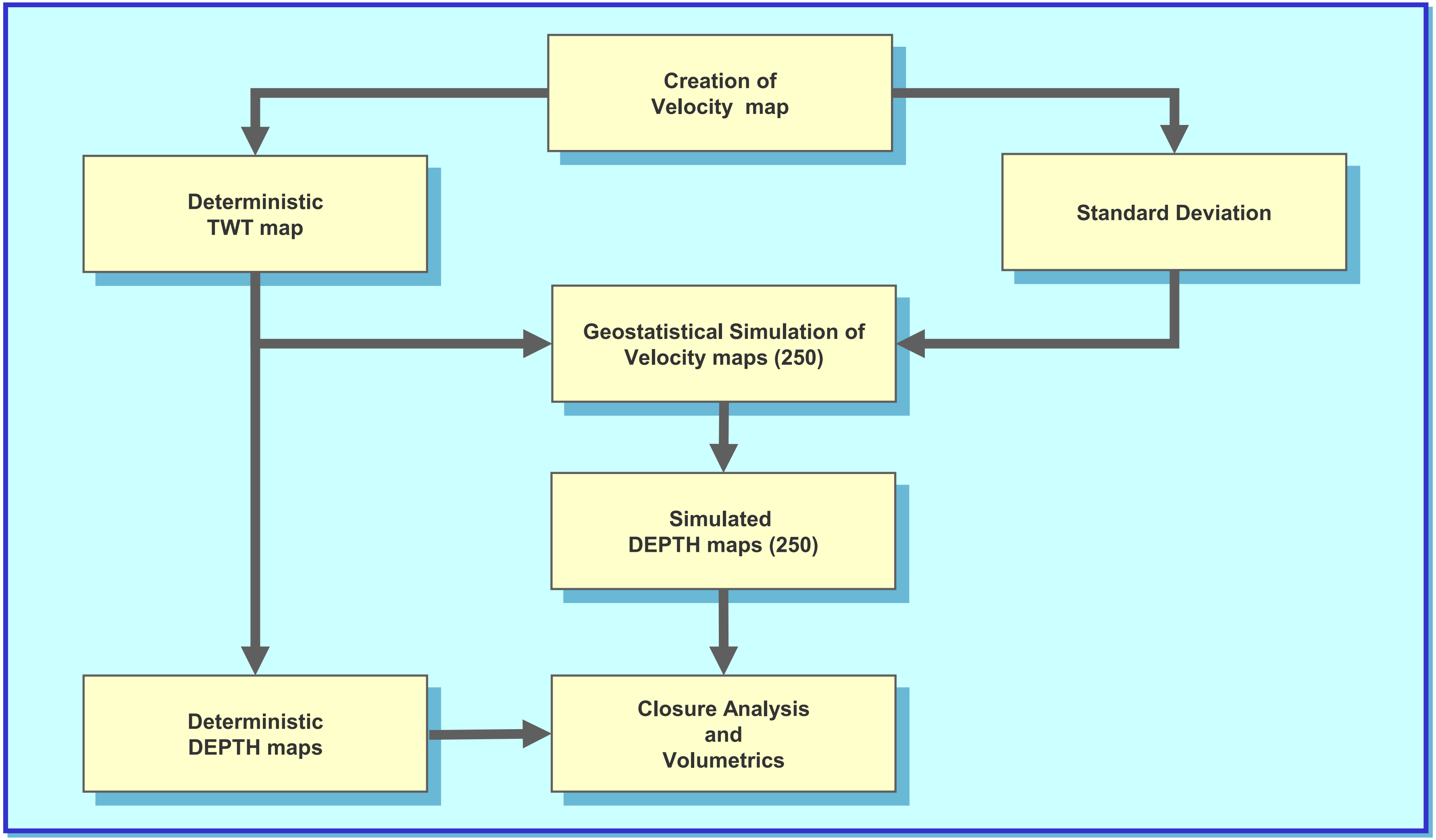
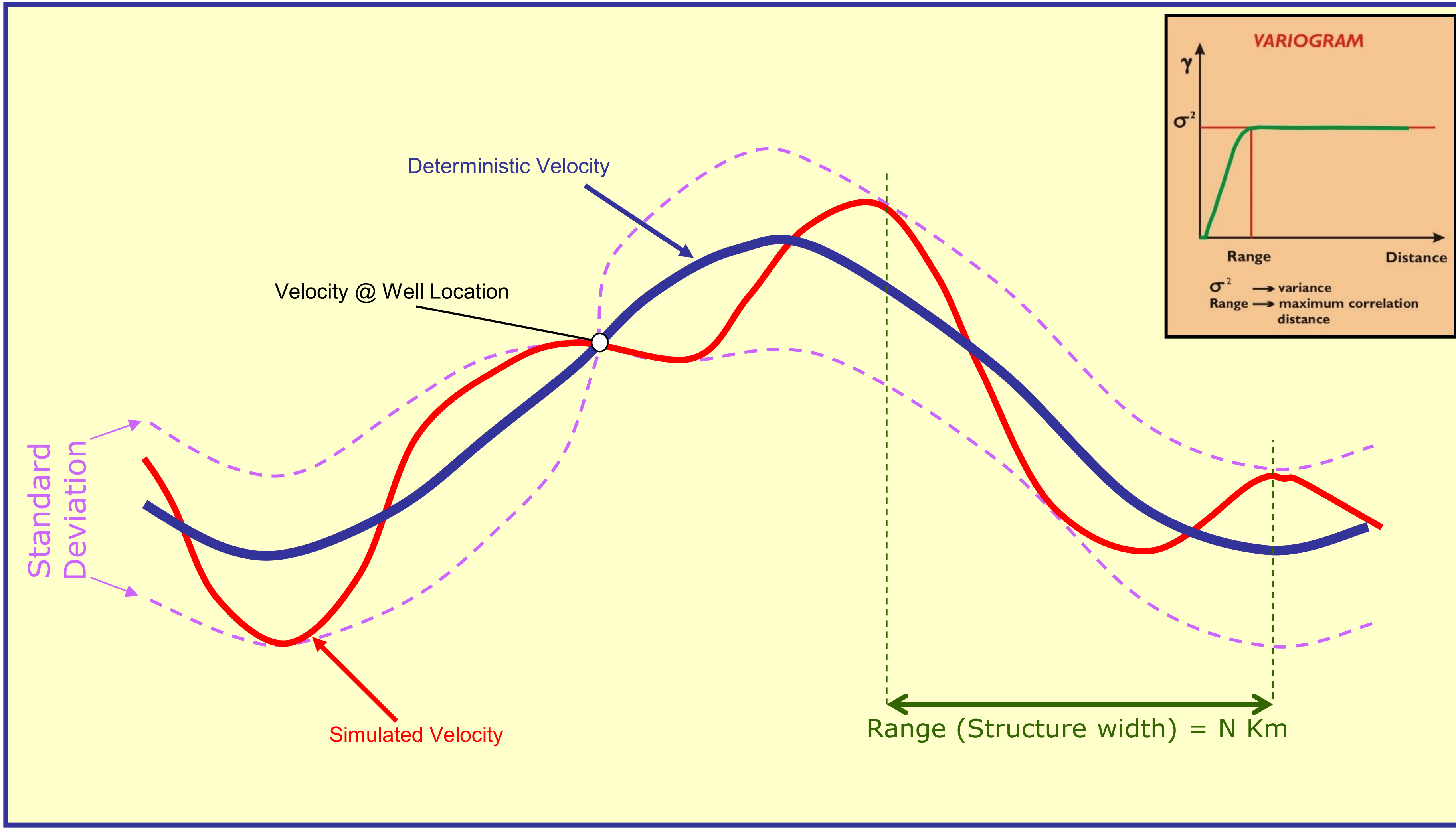
# Flowchart



Creation of Velocity map
Deterministic TWT map
Standard Deviation
Geostatistical Simulation of Velocity maps (250)
Simulated DEPTH maps (250)
Deterministic DEPTH maps
Closure Analysis and Volumetrics

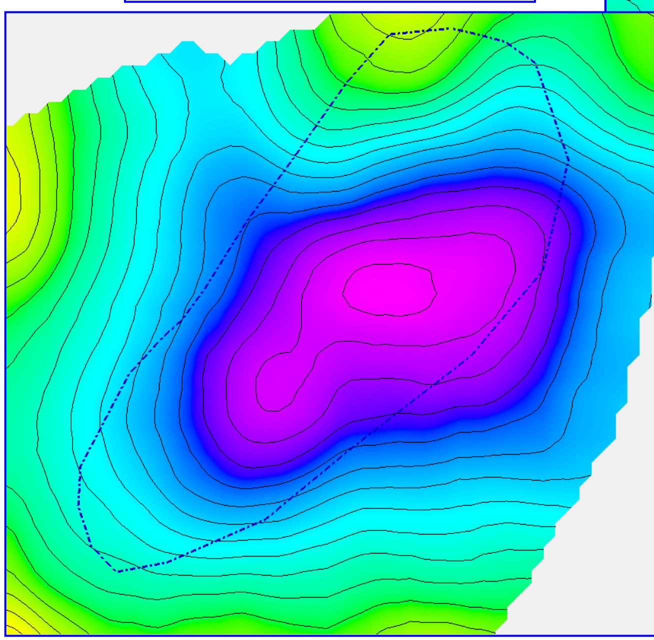
# Concepts (1)



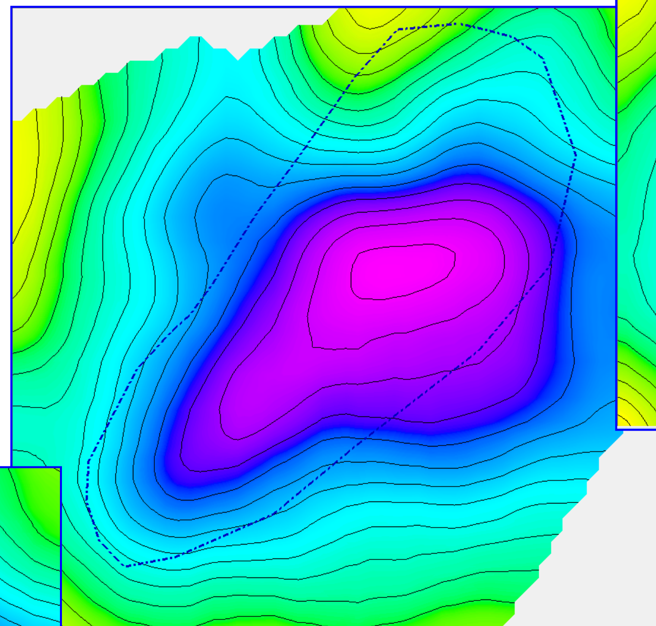
Deterministic Velocity
Velocity @ Well Location
Standard Deviation
Simulated Velocity
Range (Structure width) = N Km
VARIOGRAM
γ
σ²
Range
Distance
σ² → variance
Range → maximum correlation distance

# Concepts (2)

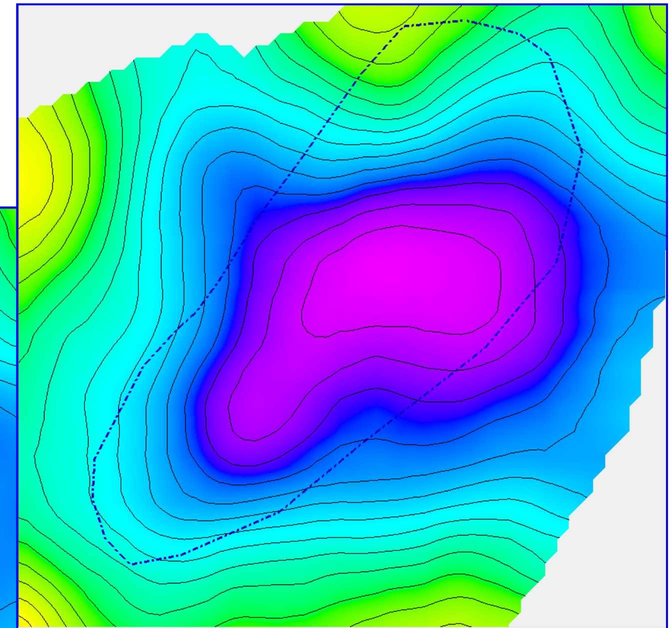
## VELOCITY MAP SIMULATIONS



*Velocity simulated map # 14*



*Velocity simulated map # 118*



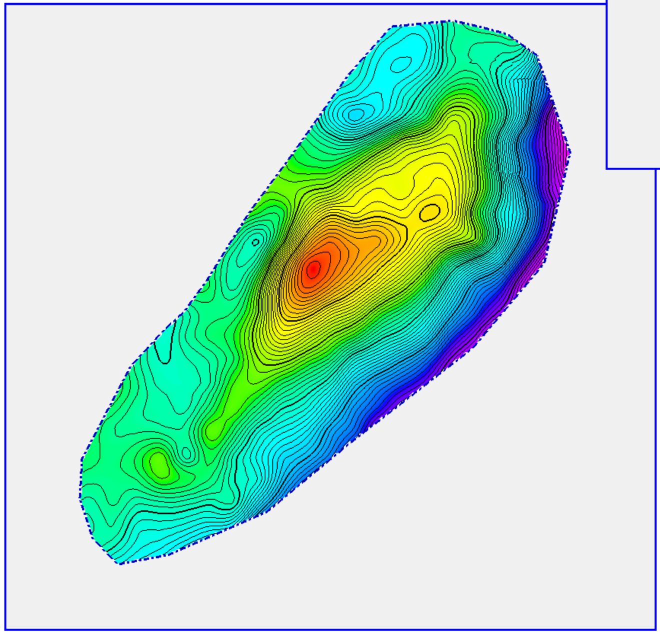
*Velocity simulated map # 224*

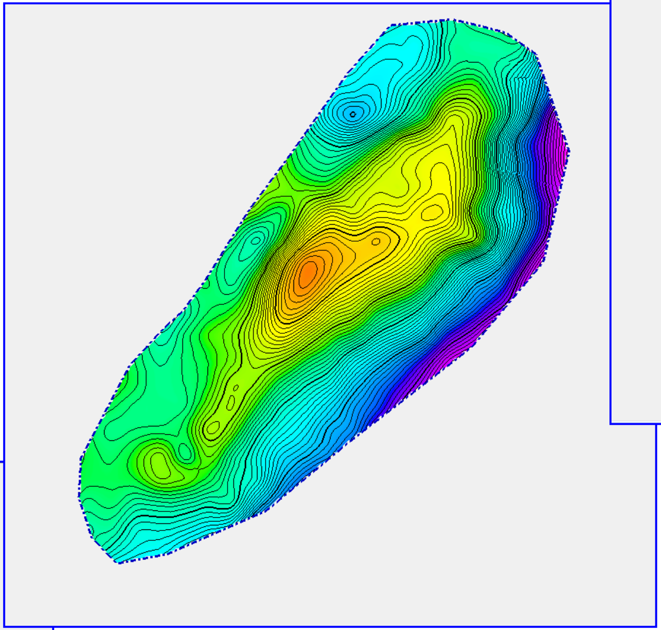
c.i. 10 m/sec

# Concepts (3)

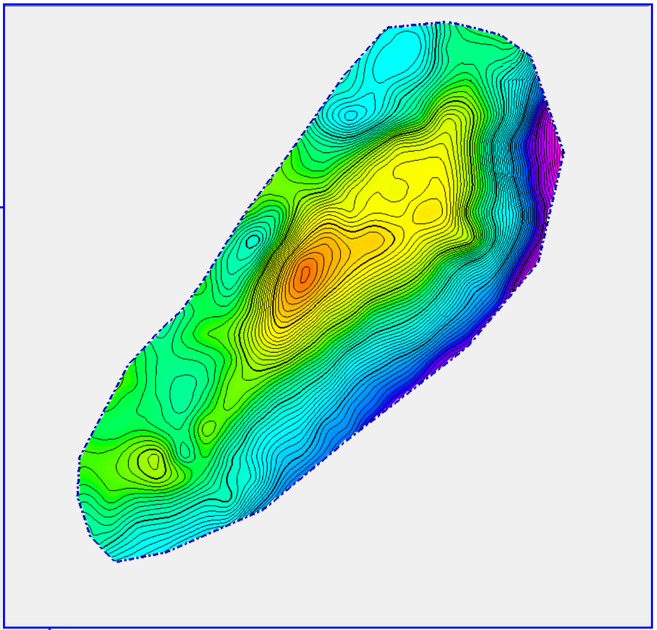
**DEPTH MAP SIMULATIONS**

*Depth simulated map # 19*





*Depth simulated map # 146*



*Depth simulated map # 242*

c.i. 10 m

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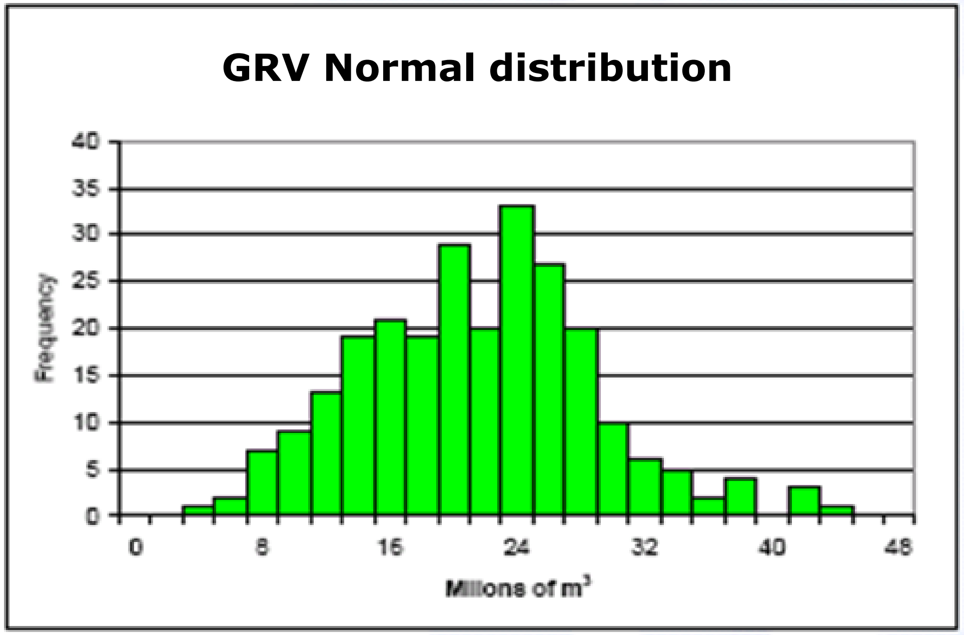
# Concepts (4)

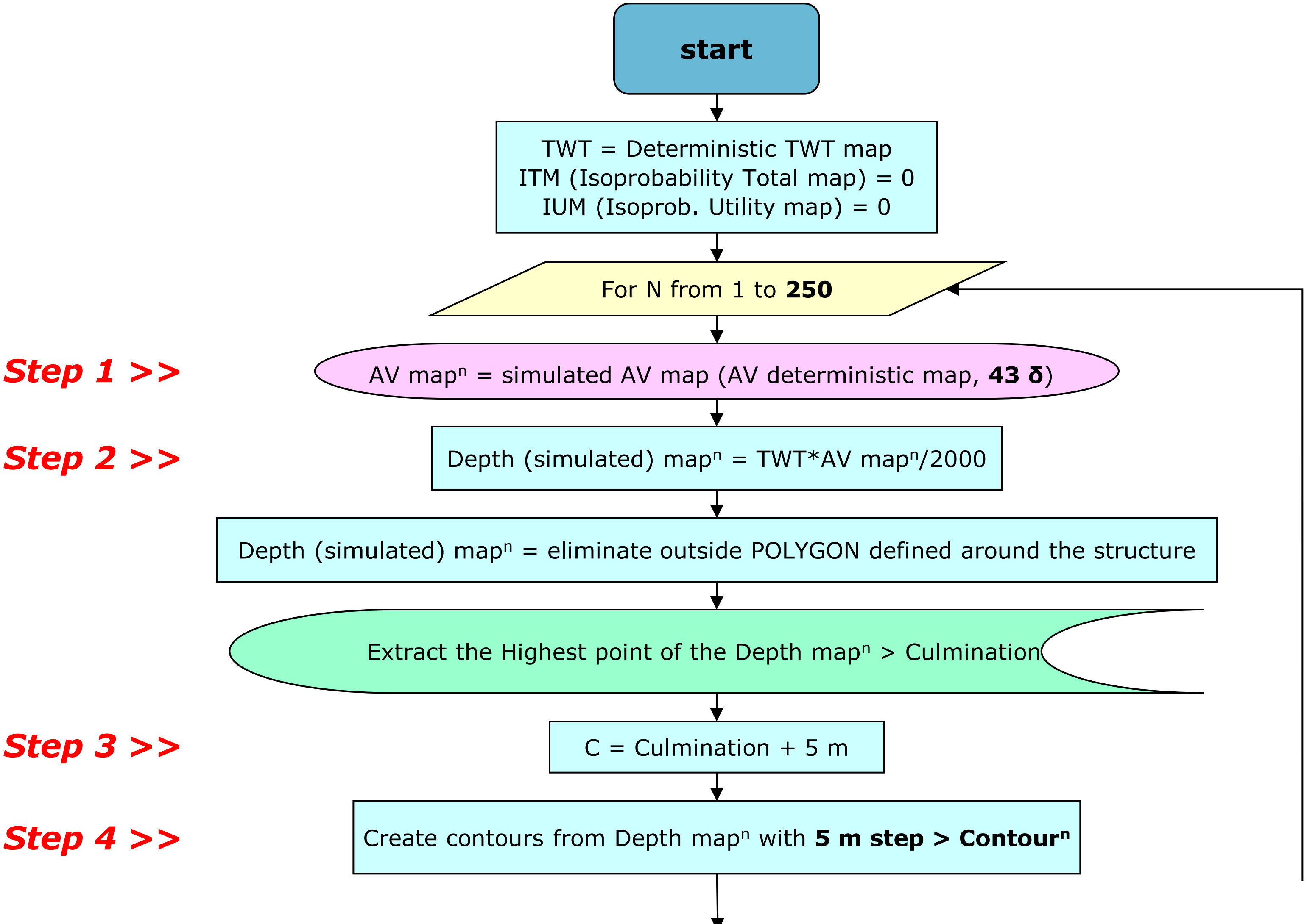



| m^3 millions | | | |
|---|---|---|---|
| P10 | 13,29 | Min | 5,73 |
| P25 | 17,26 | Max | 44,01 |
| P50 | 22,59 | Median | 22,59 |
| P75 | 27,07 | Mean | 22,48 |
| P90 | 31,40 | St.Dev. | 7,33 |

**VOLUMETRICS**

# Petrel Workflow

# Petrel workflow (1)



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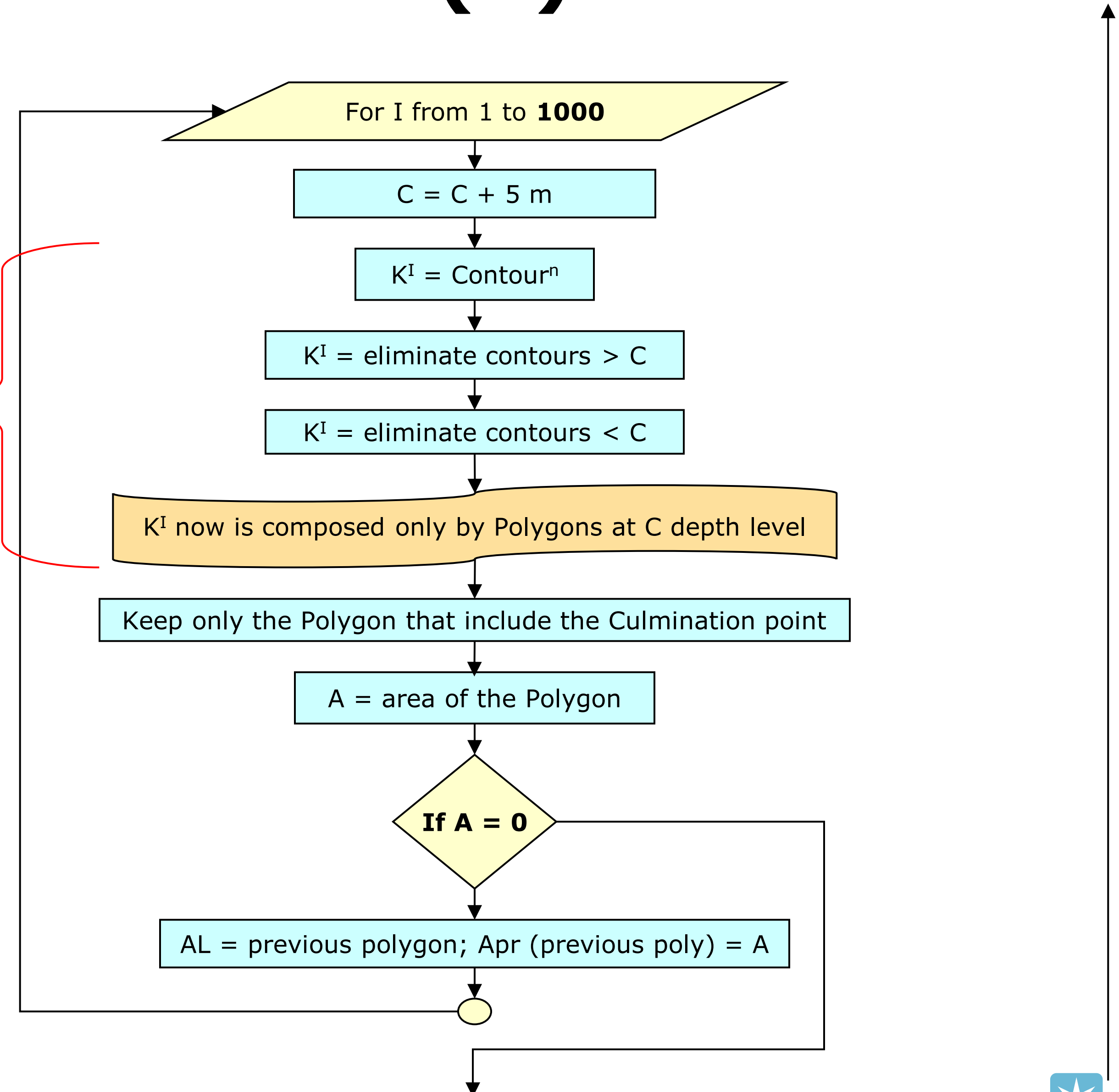
# Petrel workflow (2)




***Step 5 >>***

***Step 6 >>***

***Step 7 >>***

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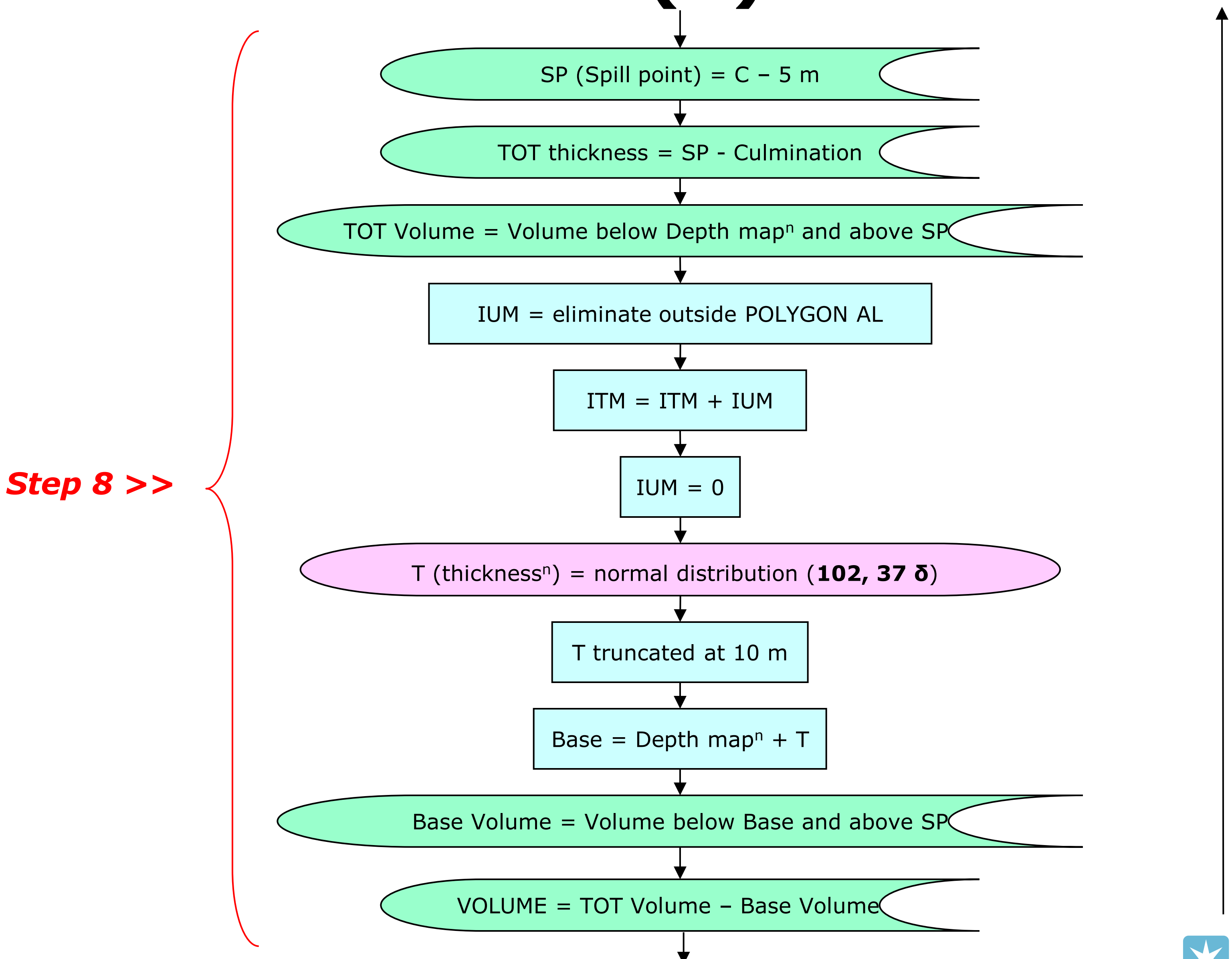
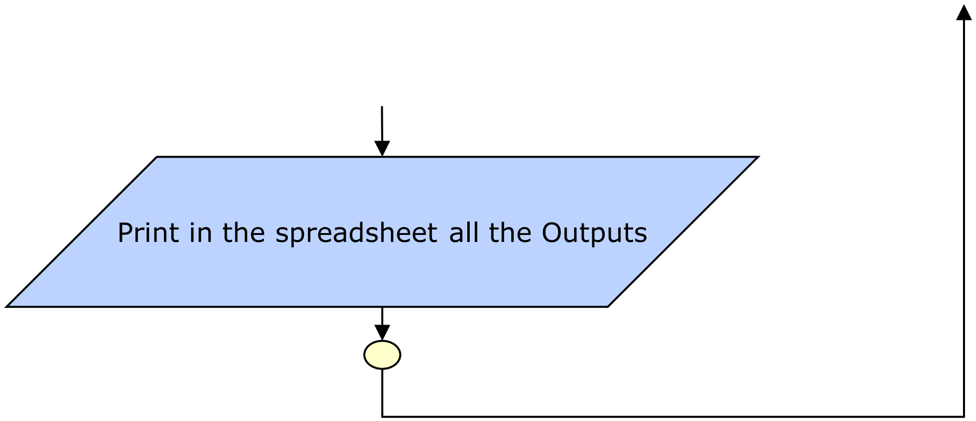
# Petrel workflow (3)



# Petrel workflow (4)



# Petrel – *Step 1* (Velocity maps creation)

| | | | | | |
|---|---|---|---|---|---|
| 16 | AV simulated map creation: for each node in the map calculates a random value by a gausian distribution | | | | |
| 17 | with Z as mean and Constant as standard deviation | | | | |
| 18 | f() Z = Normal(Z, Constant) | ⇨ | Variable Q | Constant: | 43 |

The deterministic AV map is the mean and the Standard Deviation is fixed at 43 in this case.

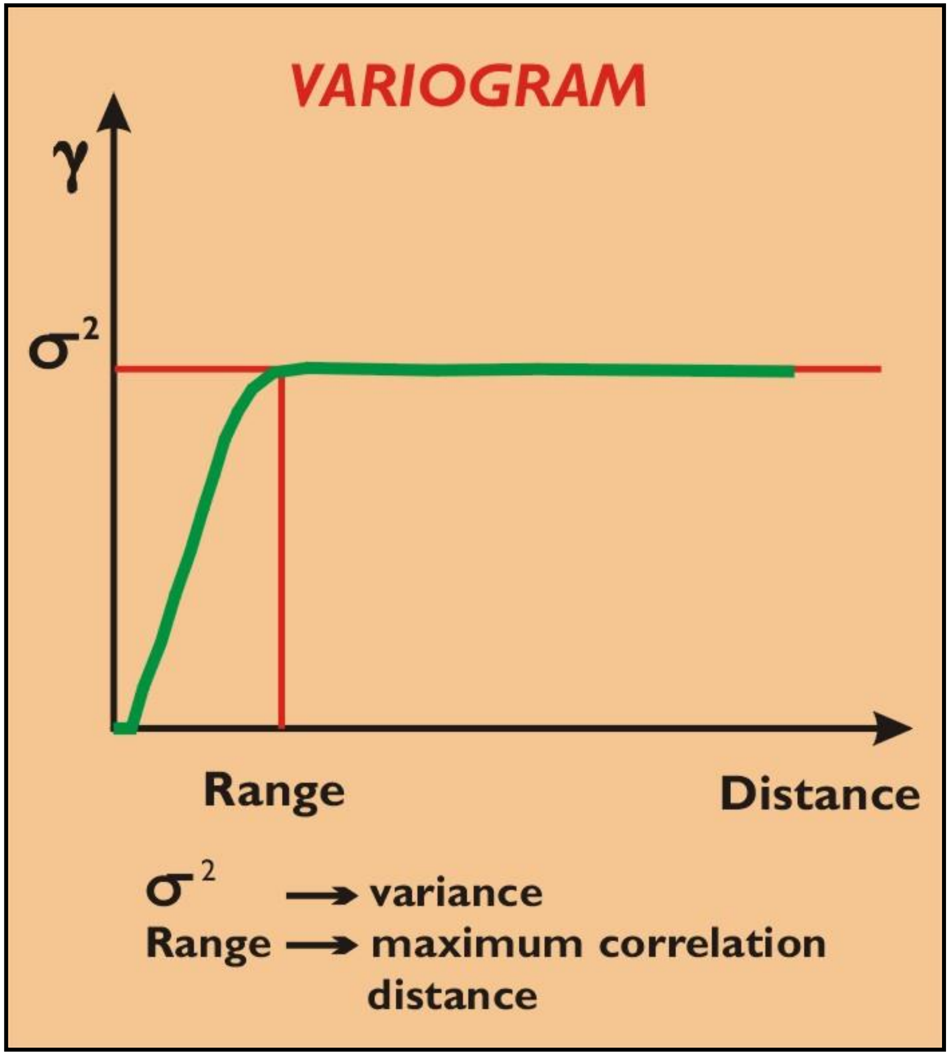
**(σ) standard deviation** is the ***critical factor*** in defining the range of the map. The Standard Deviation can be evaluated analysing geostatistically the input data (semi-variogram).

# Variogram: Theory

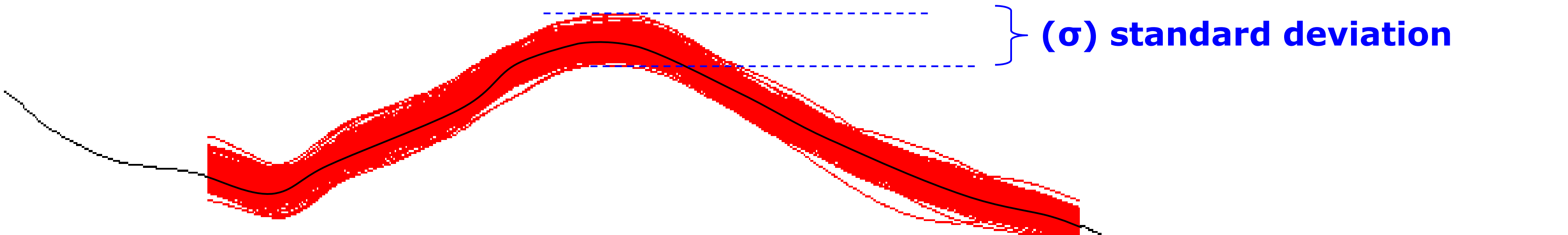
***Spatial Correlation*** = two observations are spatially correlated if when the two data are close to each other they are more likely to have similar values than when they are far apart.

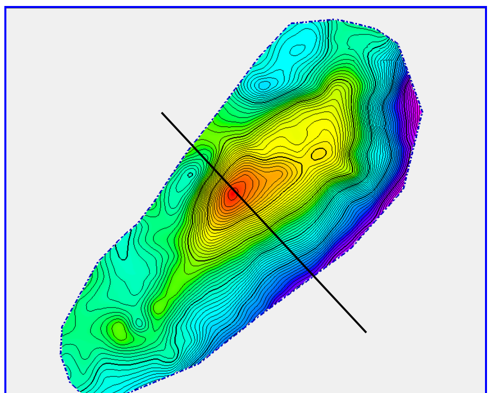
The most traditional geostatistical tools that allows to model this kind of spatial correlation is the (semi)variogram: this is a function of the distance between two observations that gives the average *lack of correlation* between these two measured values, the higher is the variogram at given distance, less correlated (similar) are the observations.

- **Range =** the observations are "not correlated" beyond this distance
- **Sill =** constant value at which the variogram reach the range; Variance of the Input Data (**σ = standard deviation**)
- **Nugget =** no correlation at zero distance (random noise)
- **Slope at the origin =** dipends on the type of variogram (Exponential, Spherical or Gaussian)

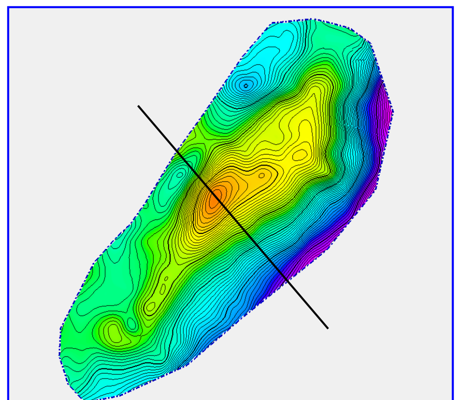


# Petrel – *Step 2* (Depth maps)



*Depth simulated map # 19*

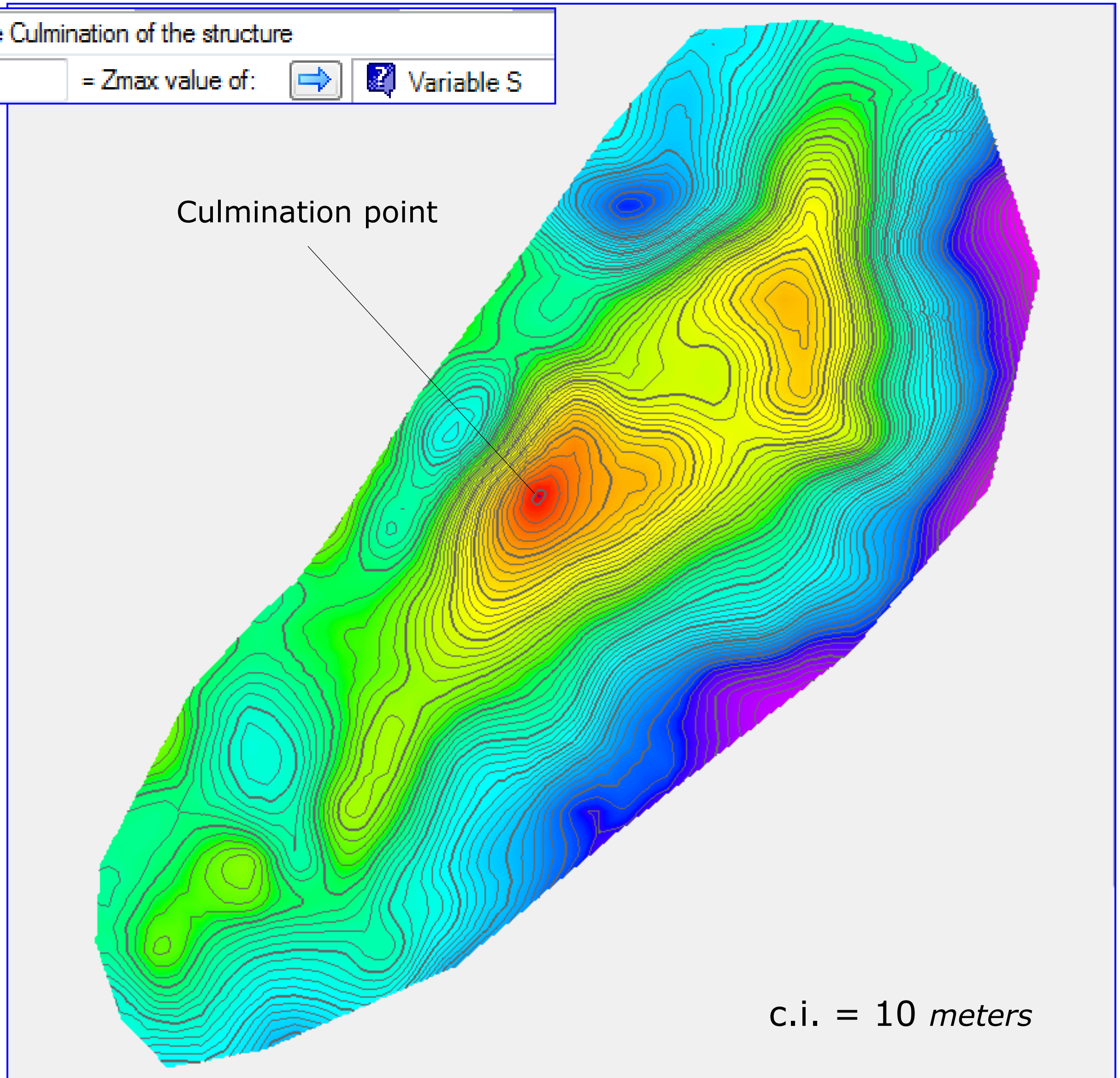


*Depth simulated map # 146*

| | | | | | |
|---|---|---|---|---|---|
| 20 | Get calculator name | $AV | → | Variable Q | |
| 21 | Get calculator name | $TWT | → | Variable M | |
| 22 | Get calculator name | $Depth | → | Variable S | |
| 23 | It calculates a Depth simulated map (s) form TWT deteministic map and AV simulated map (s) > 250 maps | | | | |
| 24 | Surface calculator | Use filter | Expression or file: | $Depth=$TWT*$AV/2000 | |

# Petrel – *Step 3* (Culmination point)

| | | | | | |
|---|---|---|---|---|---|
| 33 | | Find the Culmination of the structure | | | |
| 34 | | $Zmax | = Zmax value of: | | Variable S |

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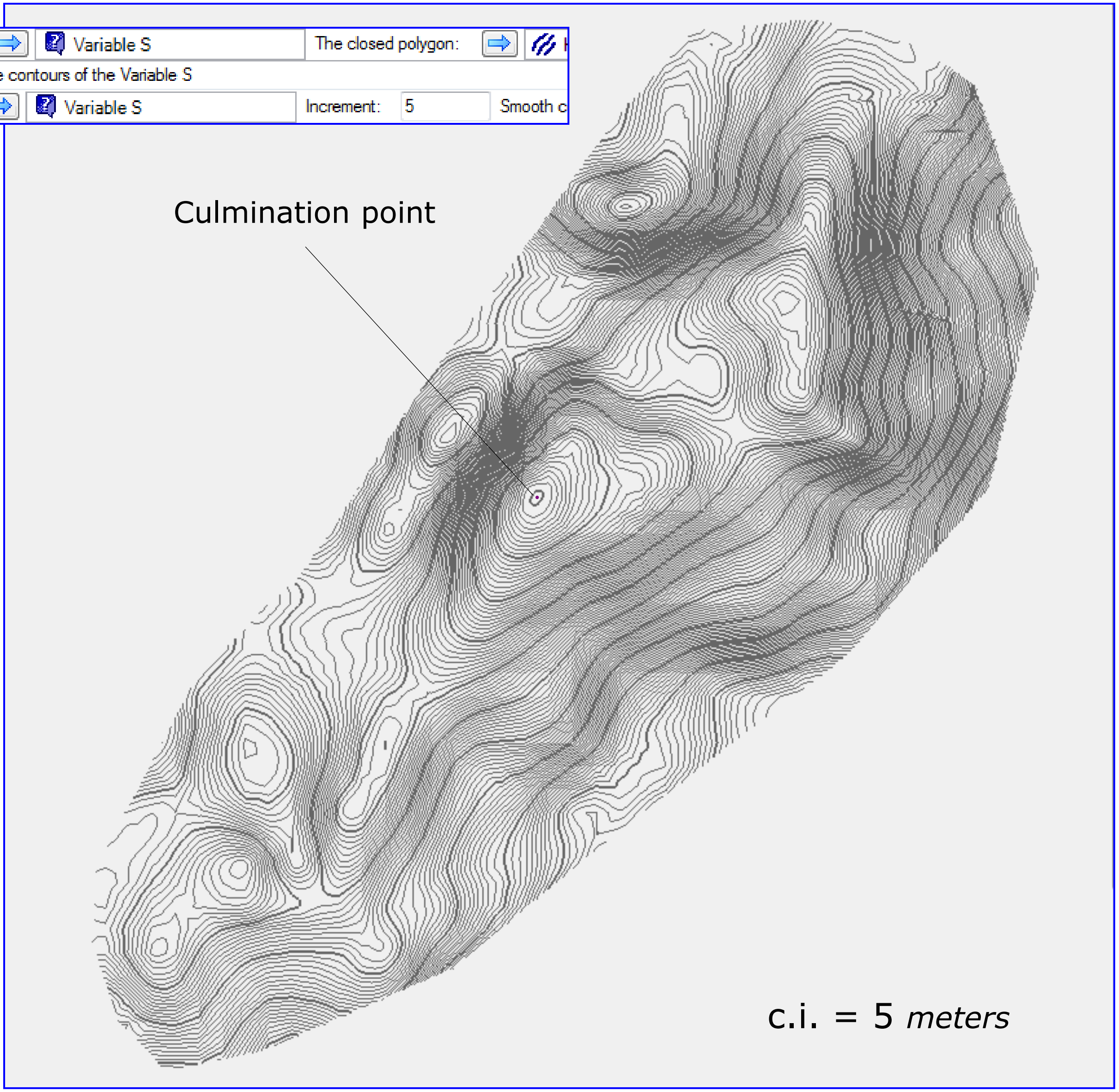
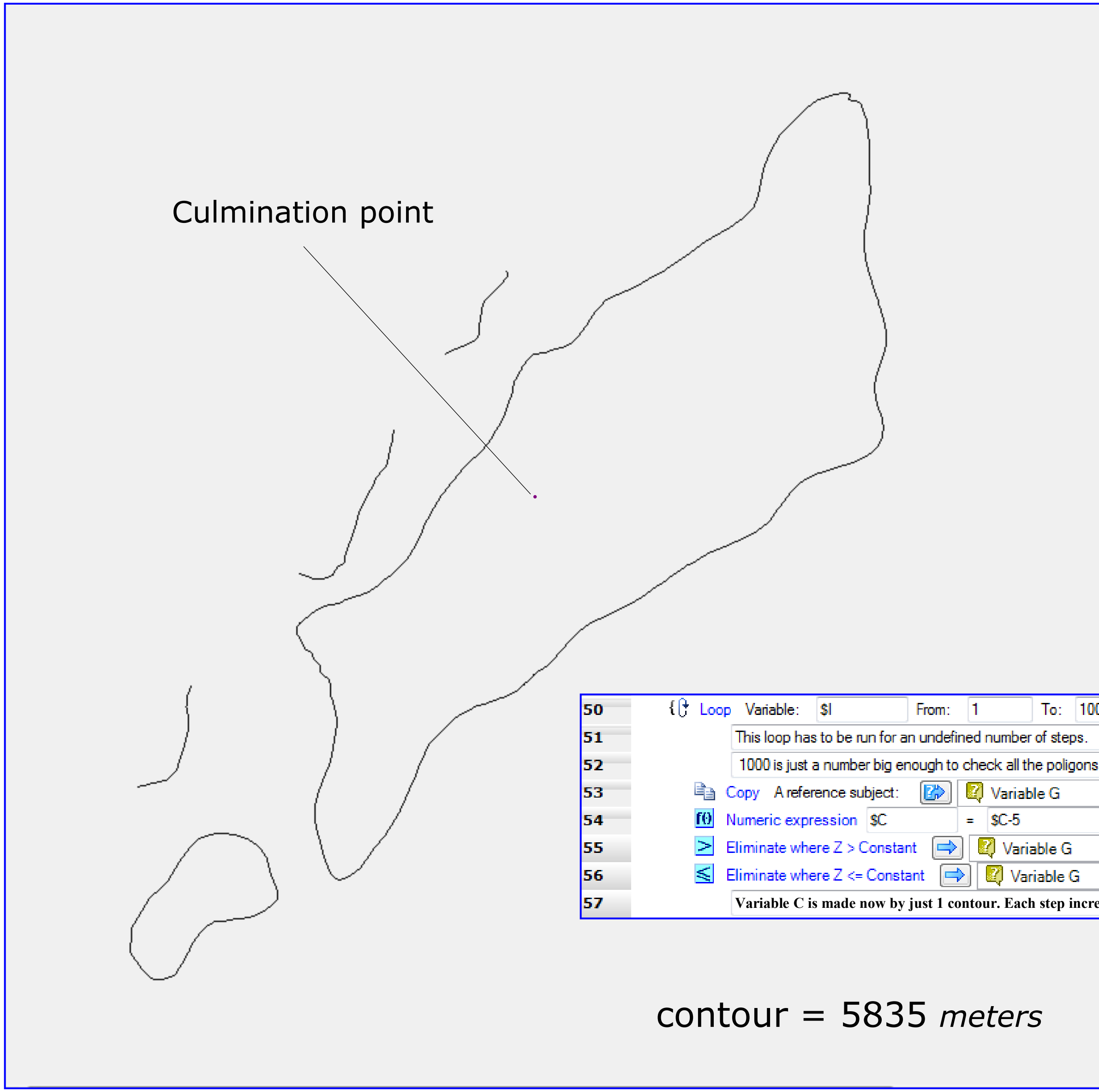
# Petrel – *Step 4* (Contours creation)

| | | | | | | |
|---|---|---|---|---|---|---|
| 29 | Eliminate outside | Variable S | The closed polygon: | | | |
| 30 | Create a file with the contours of the Variable S | | | | | |
| 31 | Create contours | Variable S | Increment: | 5 | Smooth c | |



# Petrel – *Step 5* (One contour, *N* meters)




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 50 | Loop | Variable: | $I | From: | 1 | To: | 1000 |
| 51 | This loop has to be run for an undefined number of steps. | | | | | | |
| 52 | 1000 is just a number big enough to check all the poligons (contours) from the top to the spill point. | | | | | | |
| 53 | Copy | A reference subject: | Variable G | = | Variable E | | |
| 54 | Numeric expression | $C | = | $C-5 | | | |
| 55 | Eliminate where Z > Constant | Variable G | Constant: | $C | | | |
| 56 | Eliminate where Z <= Constant | Variable G | Constant: | $C-5 | | | |
| 57 | **Variable C is made now by just 1 contour. Each step increase the polygon depth of 5 meters** | | | | | | |

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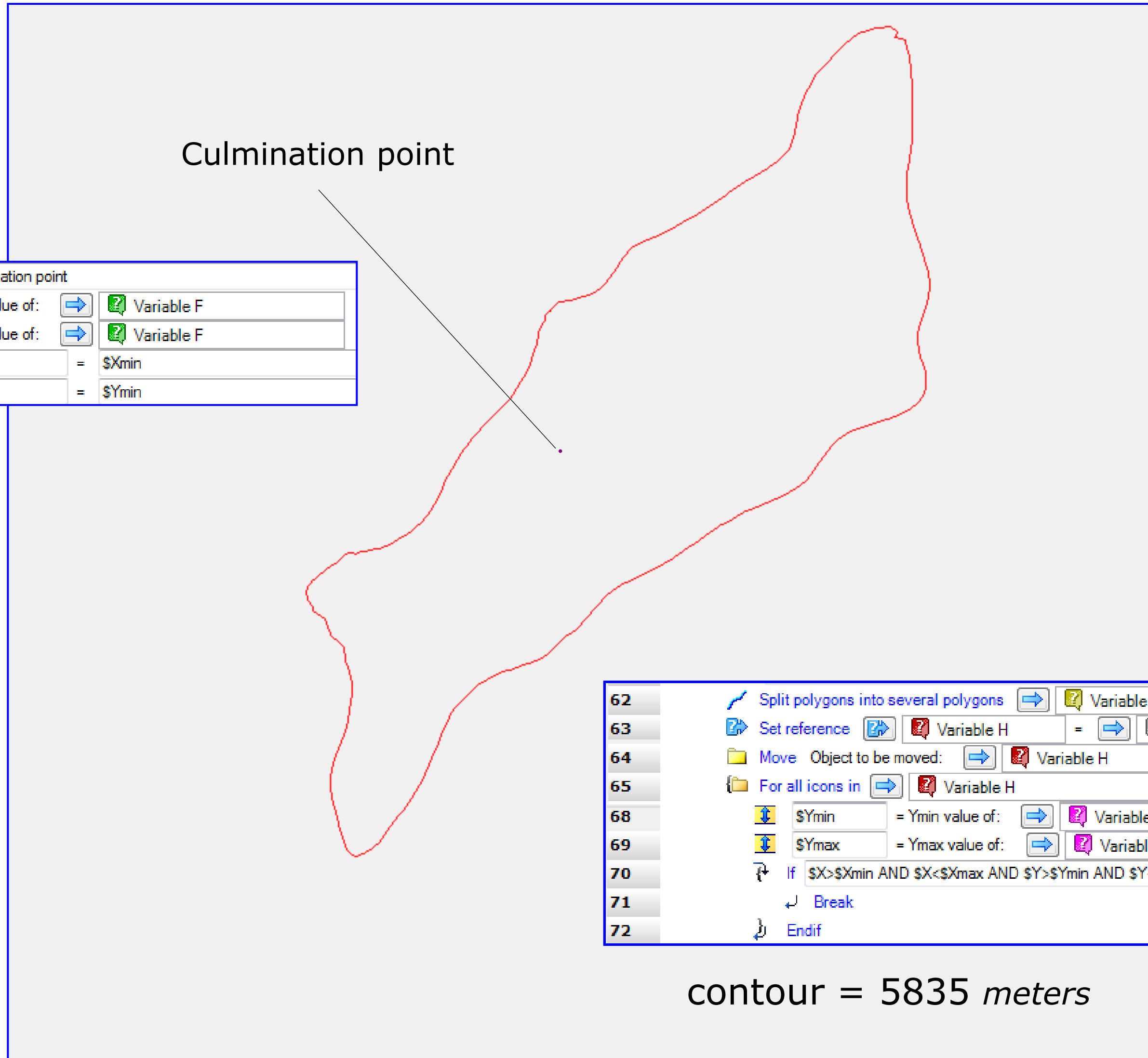
# Petrel – *Step 6* (Keep only the polygon containing the Culmination point)




| | | | | | |
|---|---|---|---|---|---|
| 43 | Get X and Y of the culmination point | | | | |
| 44 | $Xmin | = Xmin value of: | Variable F | | |
| 45 | $Ymin | = Ymin value of: | Variable F | | |
| 46 | Numeric expression | $X | = | $Xmin | |
| 47 | Numeric expression | $Y | = | $Ymin | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 62 | Split polygons into several polygons | Variable G | | | | | |
| 63 | Set reference | Variable H | = | Output | | | |
| 64 | Move | Object to be moved: | Variable H | Folder to move it into: | | | |
| 65 | For all icons in | Variable H | Child reference: | Variable I | | | |
| 68 | $Ymin | = Ymin value of: | Variable I | | | | |
| 69 | $Ymax | = Ymax value of: | Variable I | | | | |
| 70 | If | $X>$Xmin AND $X<$Xmax AND $Y>$Ymin AND $Y<$Ymax | | | | | |
| 71 | Break | | | | | | |
| 72 | Endif | | | | | | |

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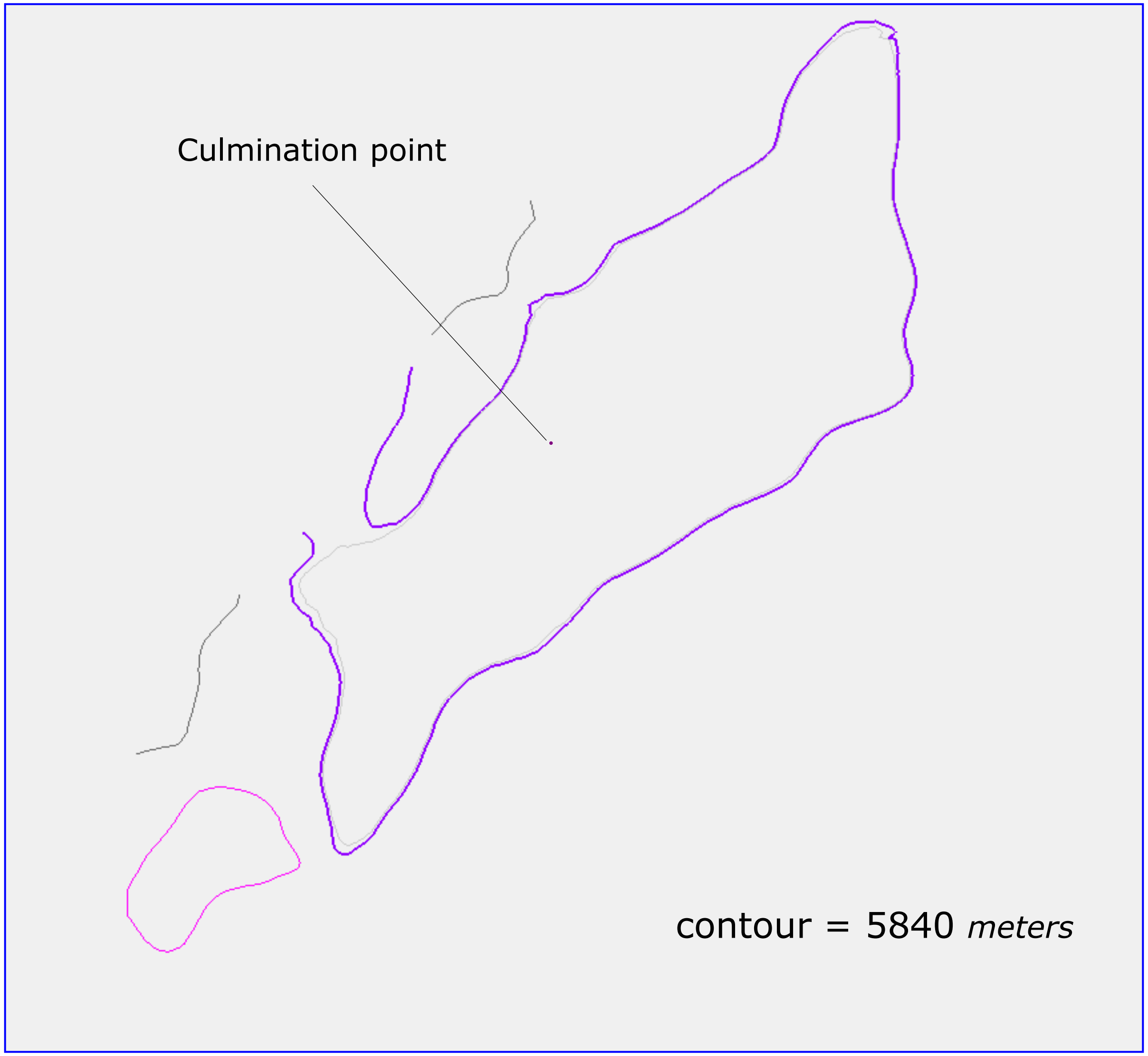
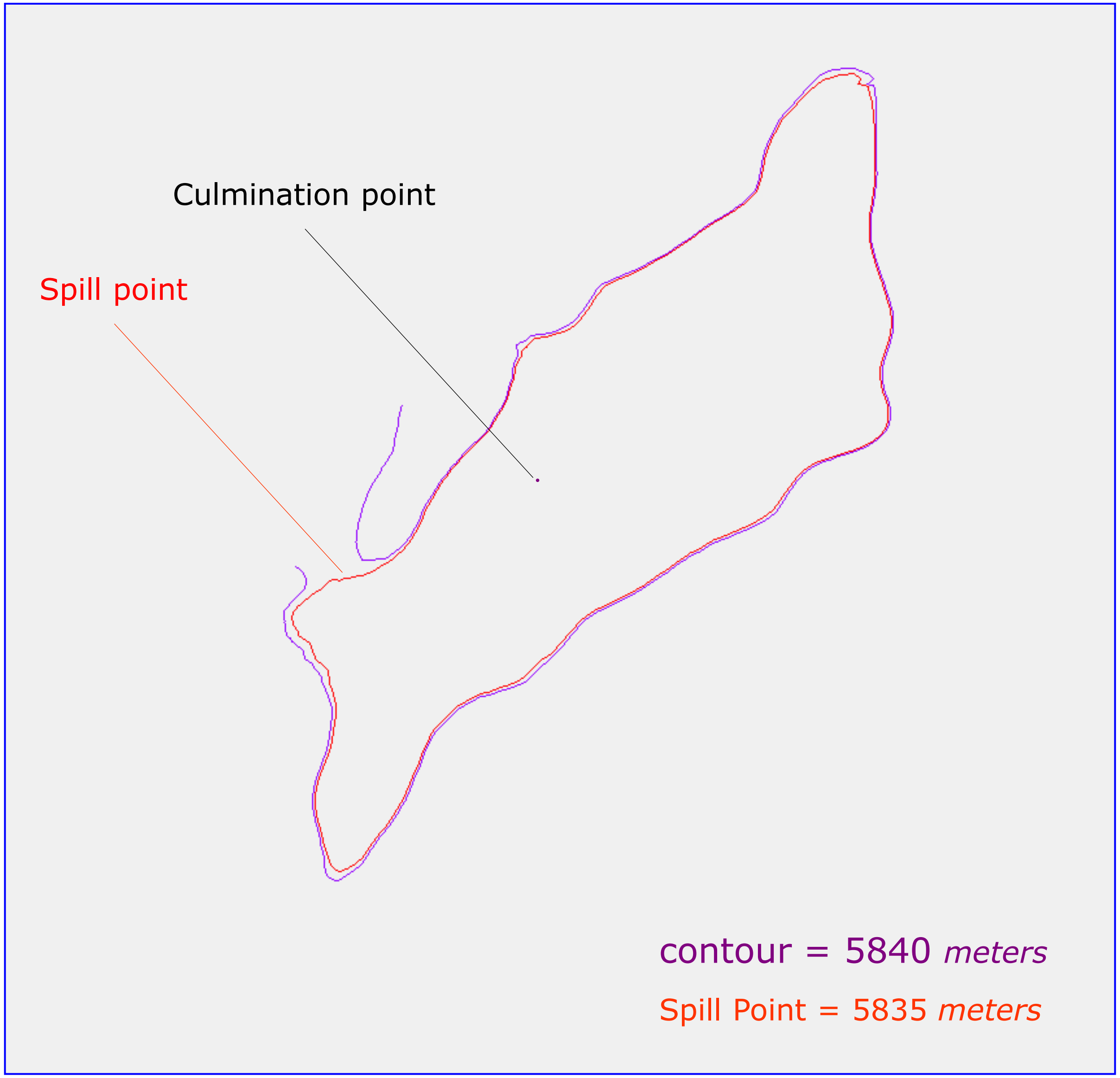
# Petrel – *Step 7* (If Area of that polygon is zero, then the contour is open)



# Petrel – *Step 8a* (Calculation – Spill Point)

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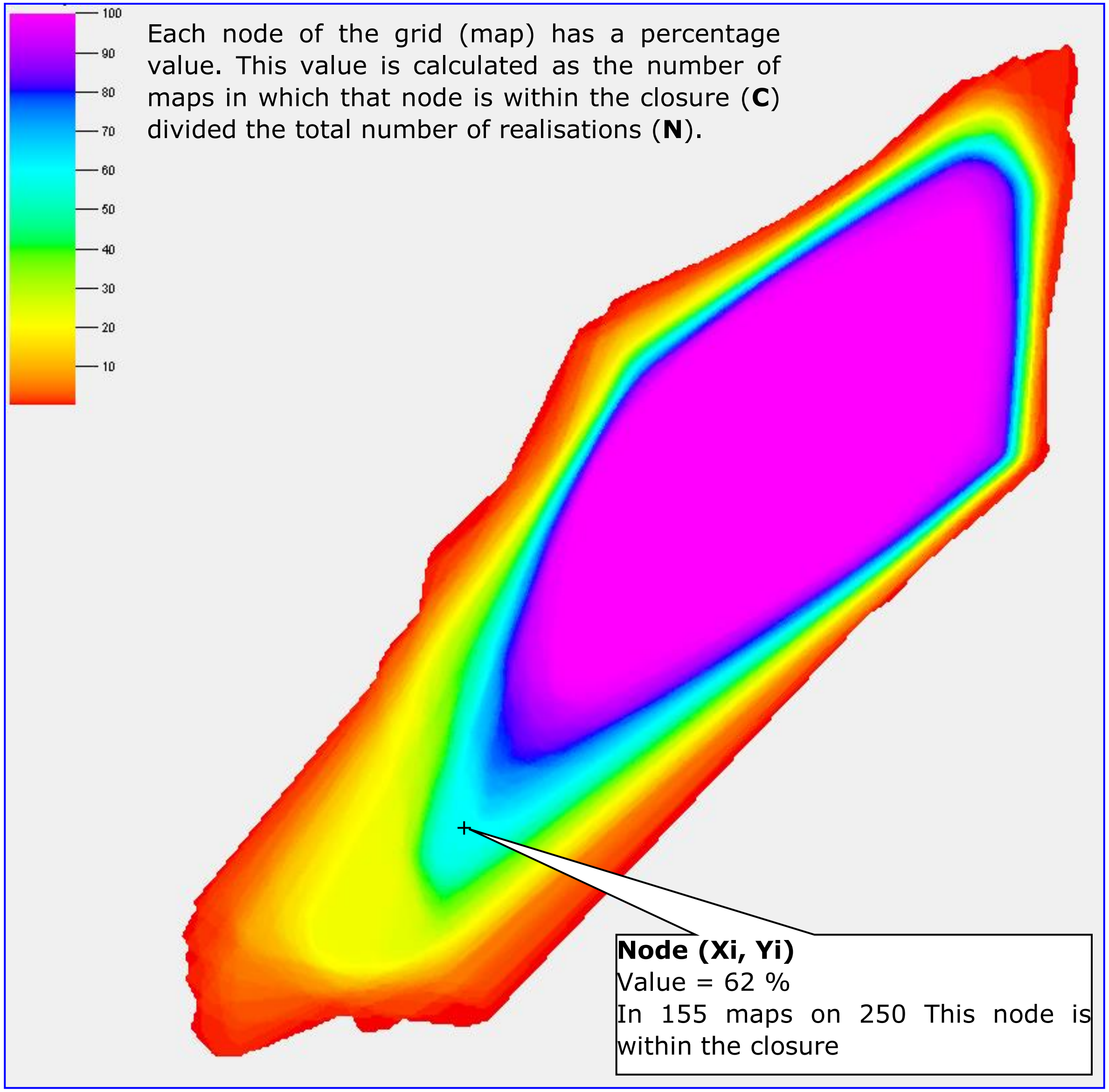
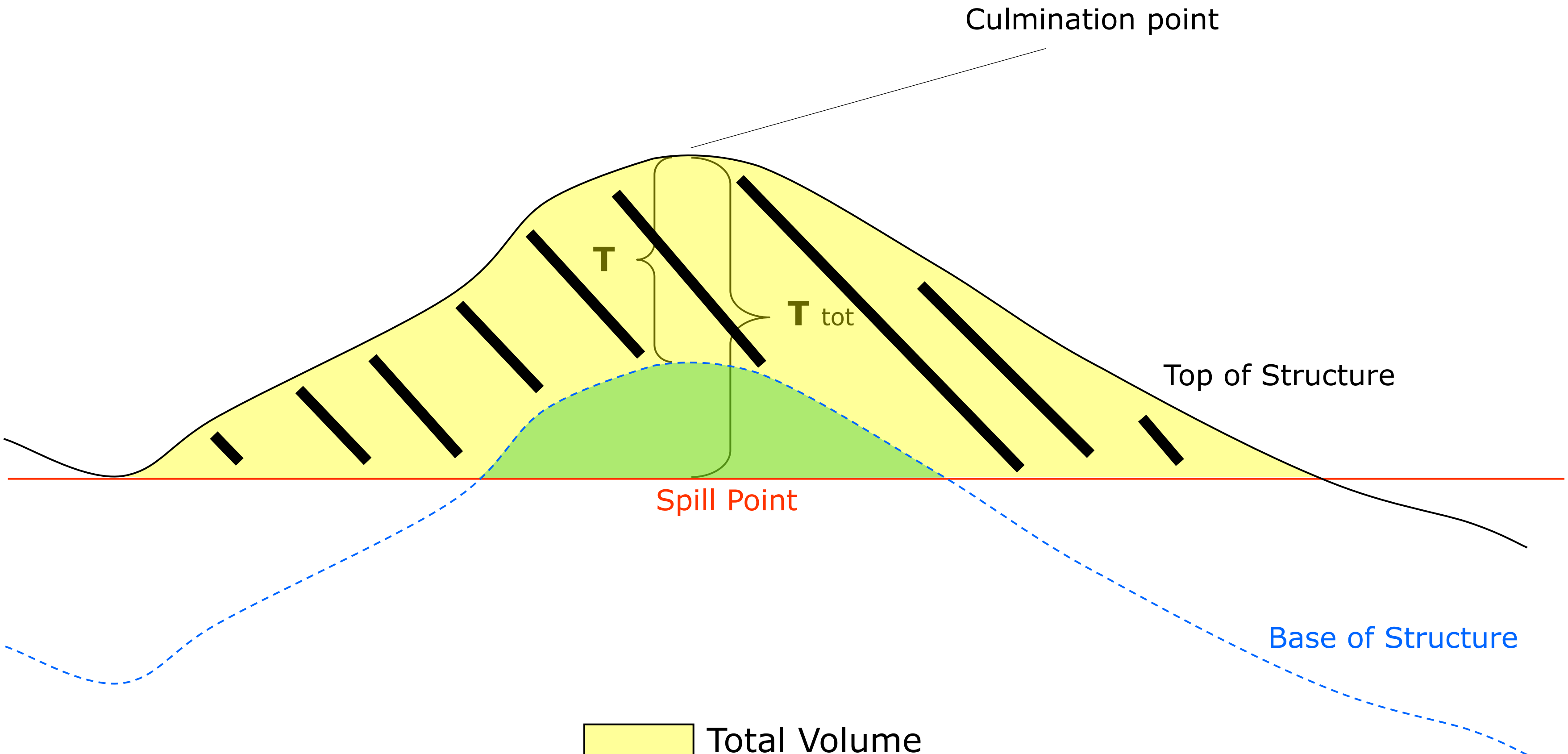
# Petrel – *Step 8b* (Isoprobability map)




Each node of the grid (map) has a percentage value. This value is calculated as the number of maps in which that node is within the closure (**C**) divided the total number of realisations (**N**).

**Node (Xi, Yi)**
Value = 62 %
In 155 maps on 250 This node is within the closure

# Petrel – *Step 8c* (Calculation)




Total Volume

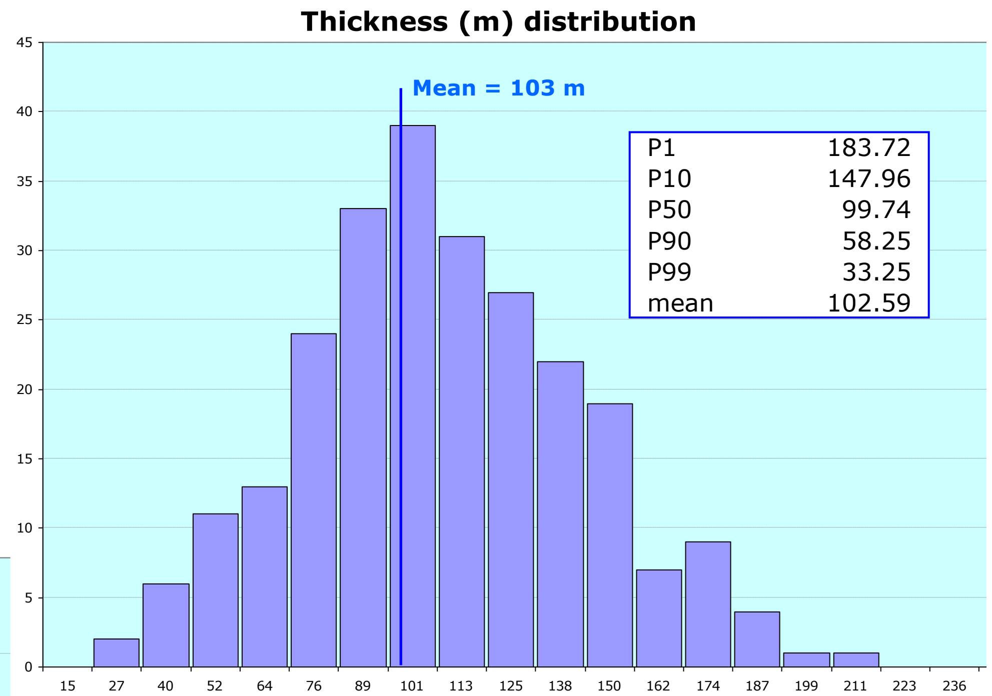
"Base" Volume

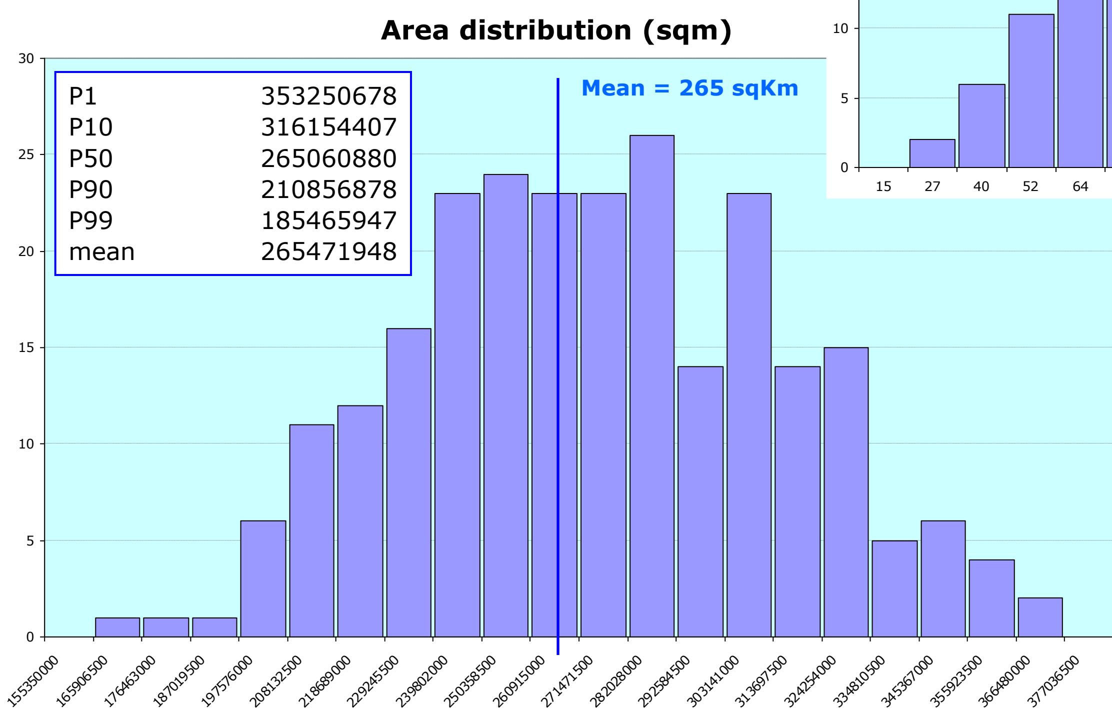
**Volume**

**T** = thickness

**T** tot = total thickness

# Petrel results



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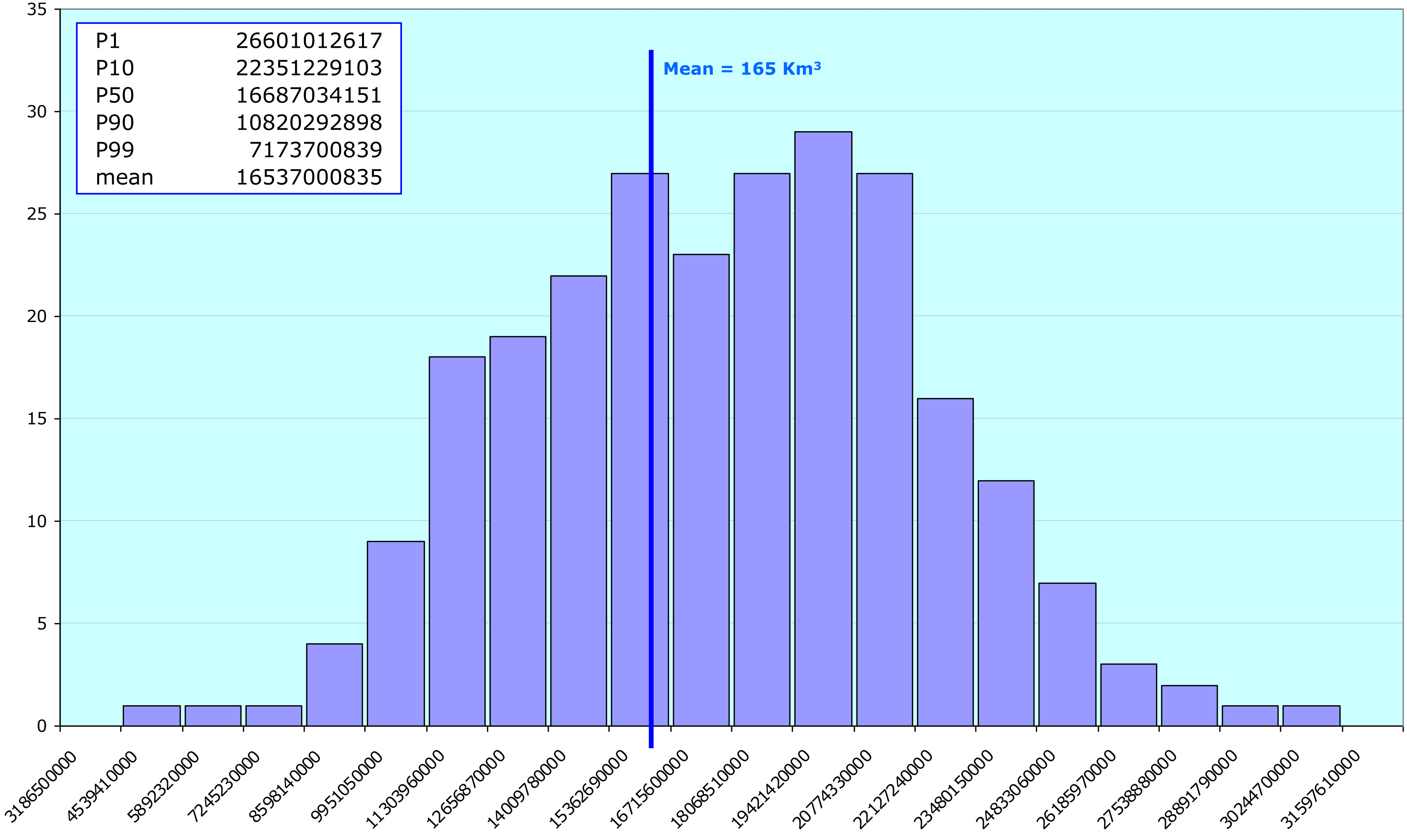
# Petrel results (GRV – m³)



# GRV ($Km^2$*m) in GeoX

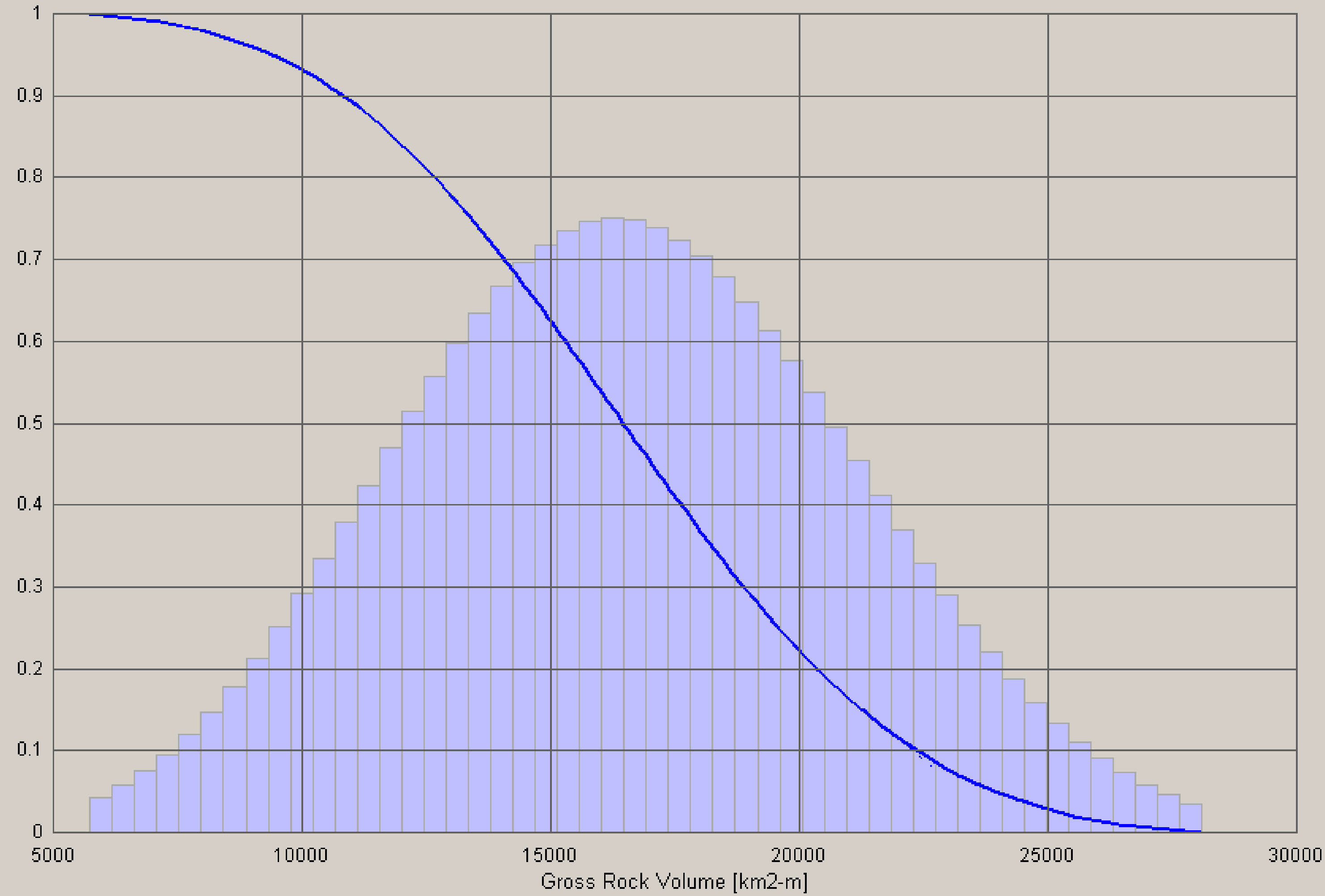
Gross Rock Volume [km2-m]

Type: 90-mean-10

X and Y-axis types: Lin-lin

Print

| | |
|---|---|
| Mean | 16537.0 |
| Std | 4364.7 |
| F100 | 5740.1 |
| F95 | 9393.4 |
| F90 | 10820.3 |
| F75 | 13412.6 |
| F50 | 16470.6 |
| F25 | 19594.2 |
| F10 | 22351.2 |
| F05 | 23916.1 |
| F00 | 28101.9 |
| | |
| Min | 5740.1 |
| Max | 28101.9 |
| Med | 16470.6 |
| Mod | 16311.6 |
| F10:90 | 2.07 |



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Type: 90-mean-10

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Print

| | |
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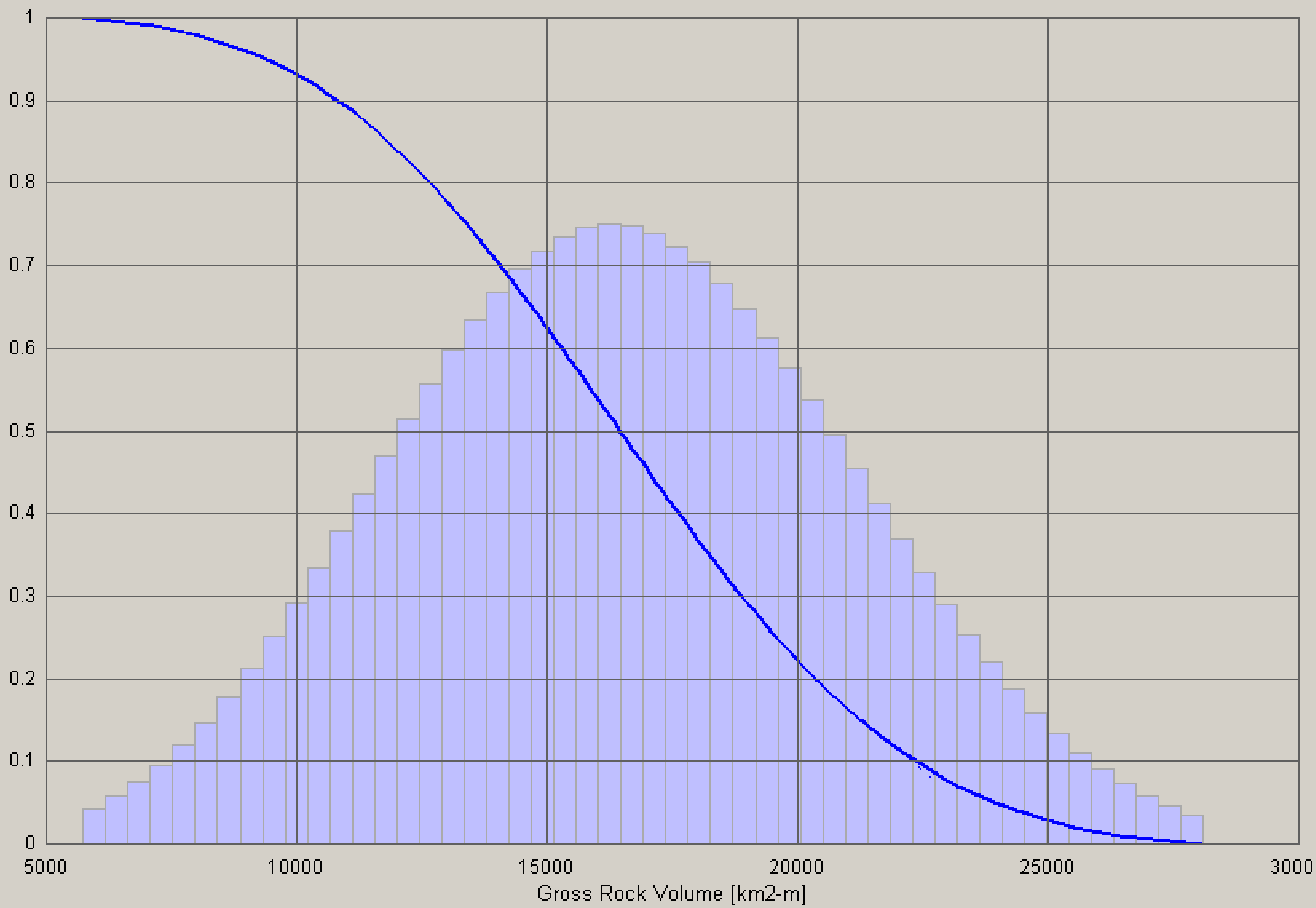
| F90 | 10820.3 |
| F75 | 13412.6 |
| F50 | 16470.6 |
| F25 | 19594.2 |
| F10 | 22351.2 |
| F05 | 23916.1 |
| F00 | 28101.9 |
| | |
| Min | 5740.1 |
| Max | 28101.9 |
| Med | 16470.6 |
| Mod | 16311.6 |
| F10:90 | 2.07 |

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# Recoverable Resources in GeoX

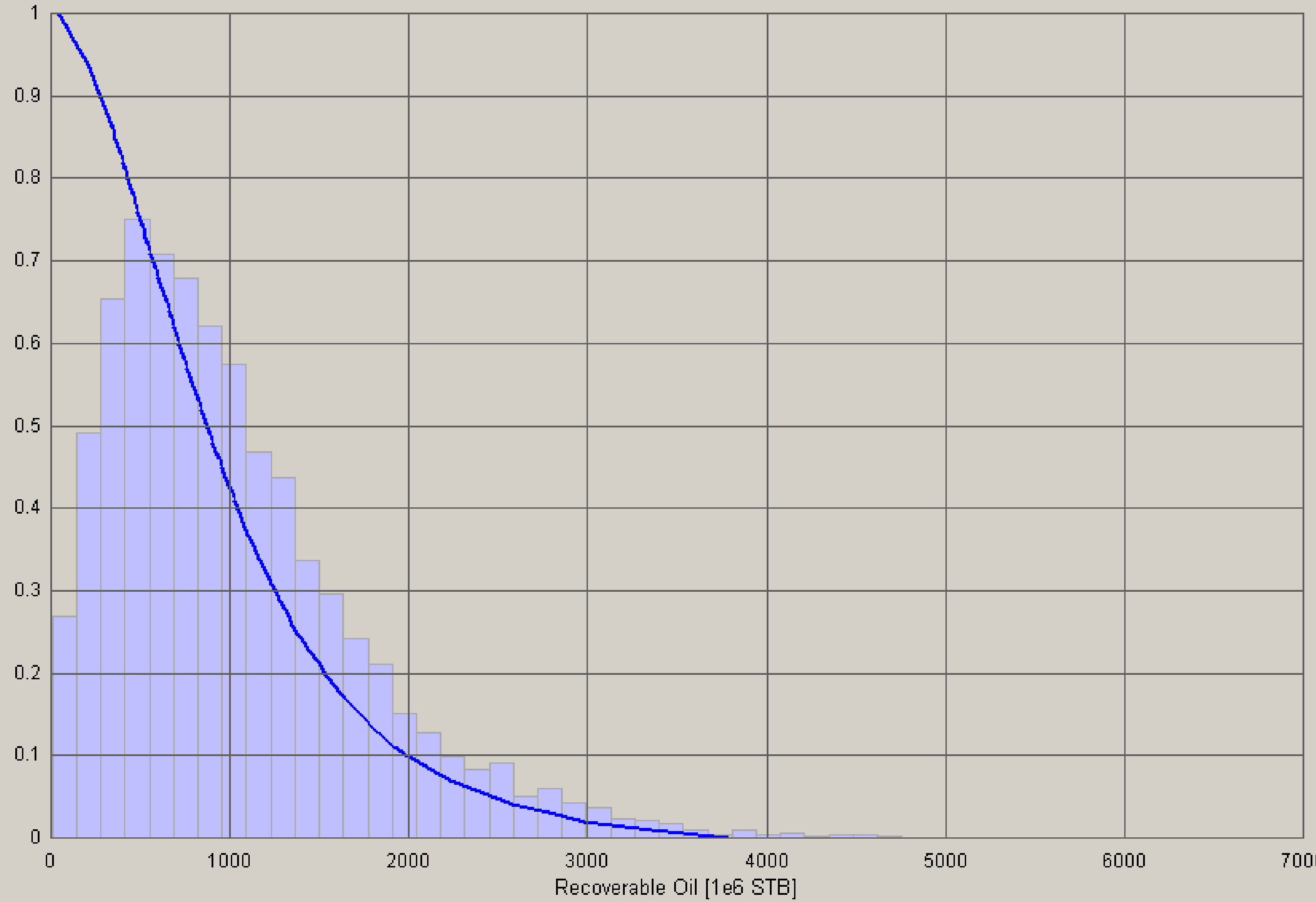
Recoverable Oil [1e6 STB]

Type: MC(10000)

X and Y-axis types: Lin-lin

Print

| | |
|---|---|
| Mean | 1030.4 |
| Std | 721.0 |
| F100 | 44.8 |
| F95 | 177.3 |
| F90 | 277.5 |
| F75 | 498.4 |
| F50 | 869.9 |
| F25 | 1377.5 |
| F10 | 1977.1 |
| F05 | 2462.5 |
| F00 | 3792.4 |
| | |
| Min | 44.8 |
| Max | 3792.4 |
| Med | 869.9 |
| Mod | N/A |
| F10:90 | 7.12 |

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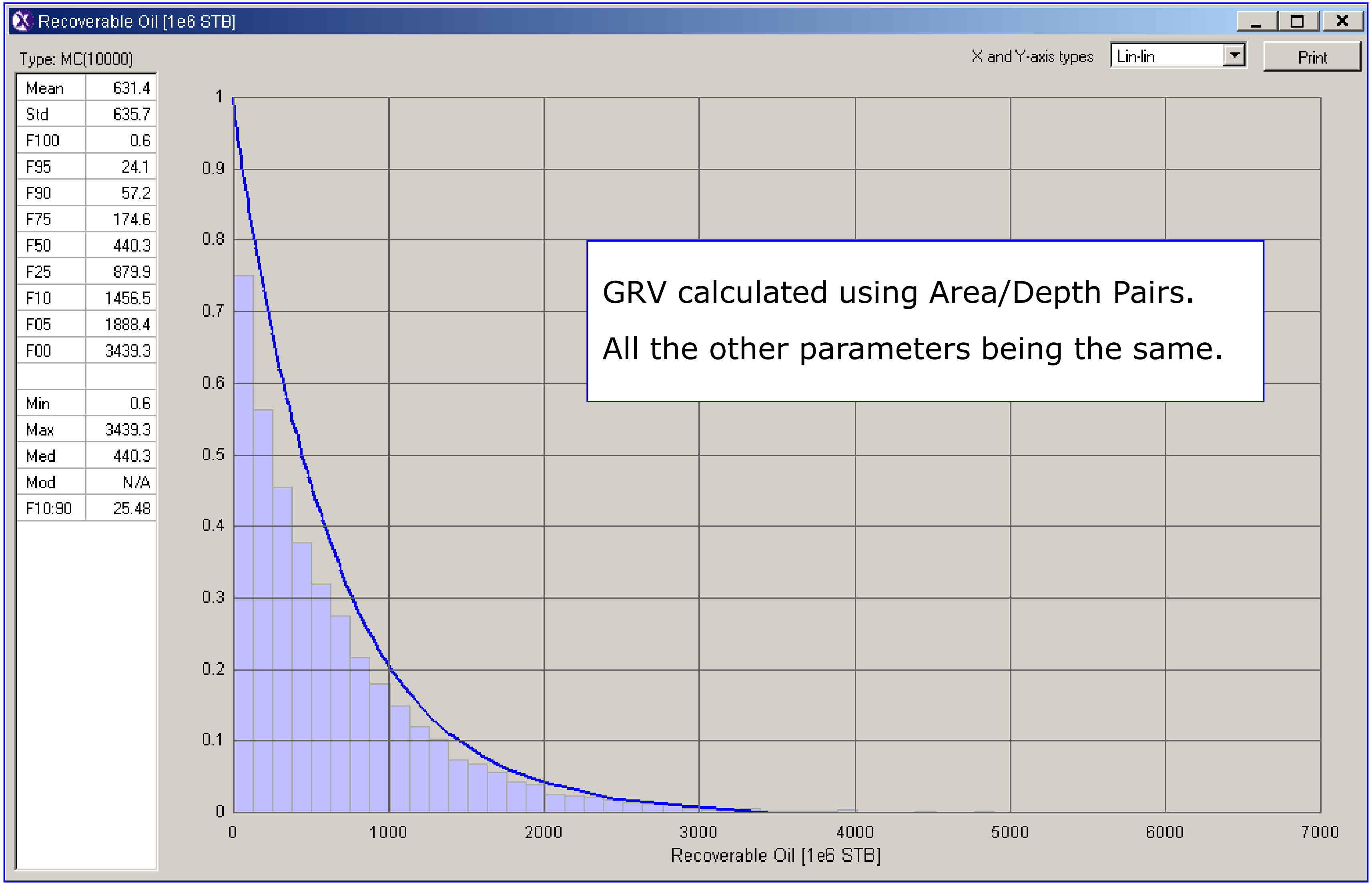
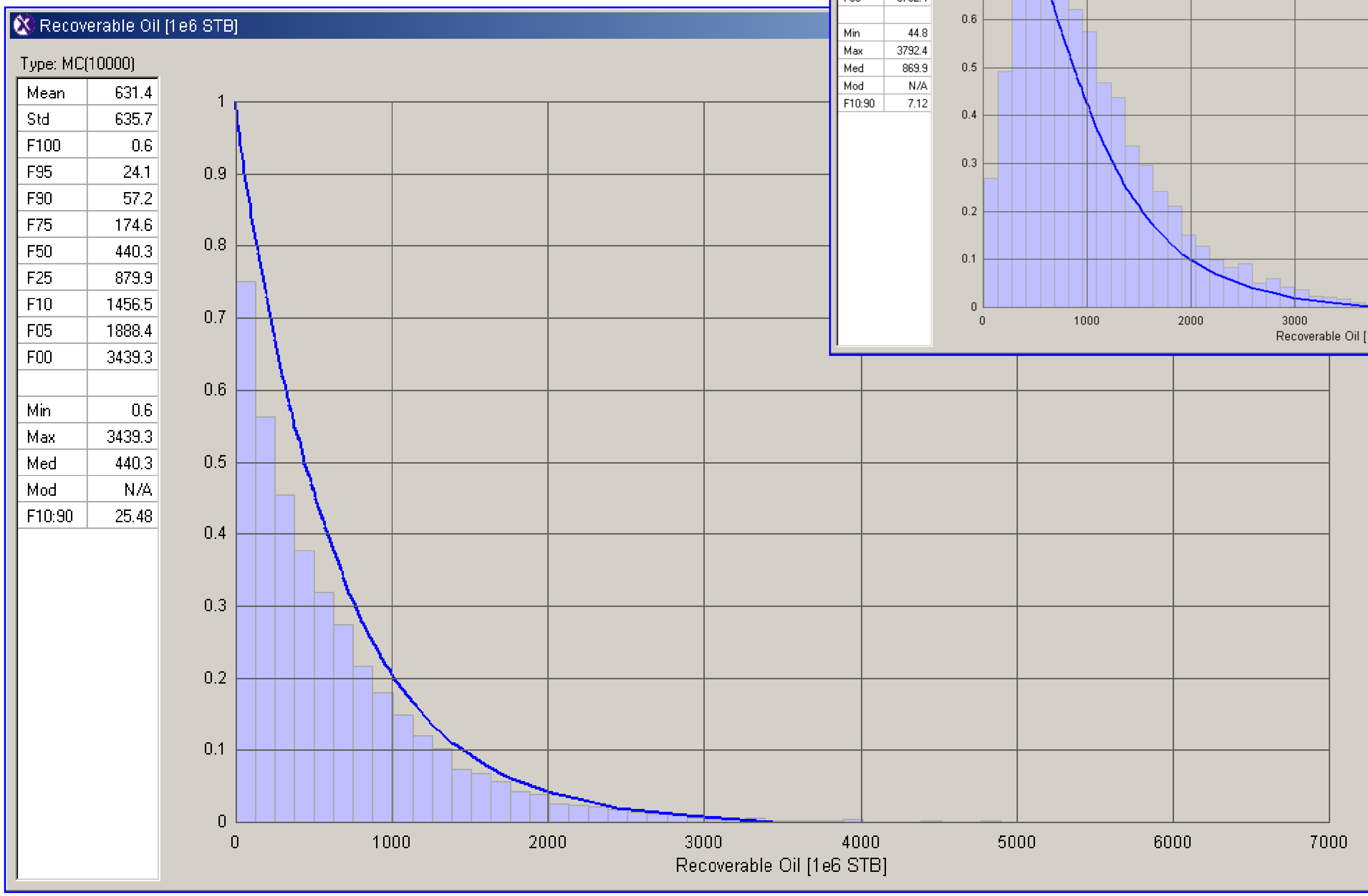
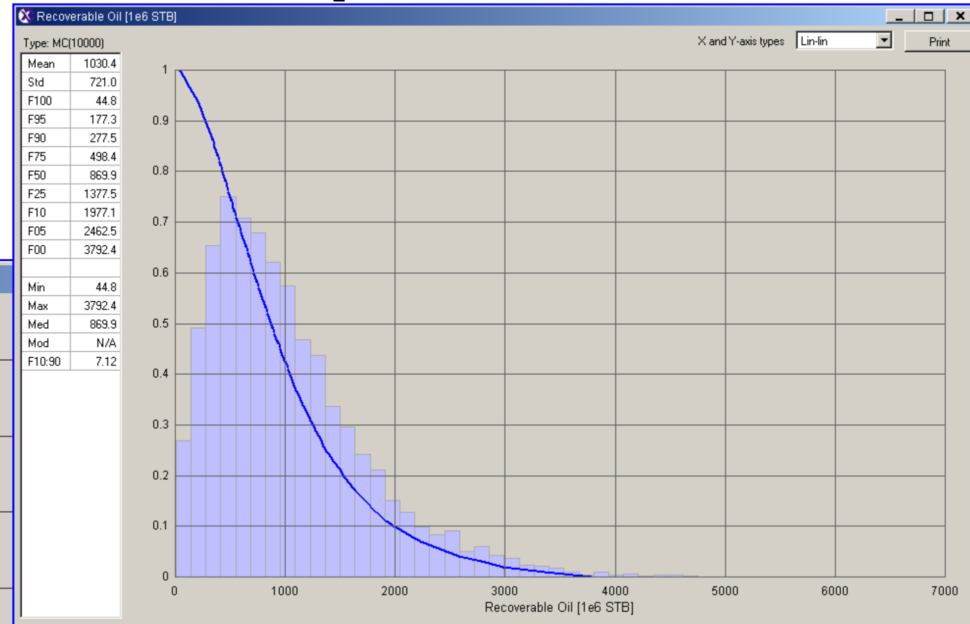
# Area/Depth Pairs




| | |
|---|---|
| Mean | 631.4 |
| Std | 635.7 |
| F100 | 0.6 |
| F95 | 24.1 |
| F90 | 57.2 |
| F75 | 174.6 |
| F50 | 440.3 |
| F25 | 879.9 |
| F10 | 1456.5 |
| F05 | 1888.4 |
| F00 | 3439.3 |
| | |
| Min | 0.6 |
| Max | 3439.3 |
| Med | 440.3 |
| Mod | N/A |
| F10:90 | 25.48 |

# Petrel simulations vs. Area/Depth Pairs



# Open problems

- Faults position
- Compartmentalization (fault sealing)
- Connectivity

**ANY SUGGESTION ???**

# Back-up

# Spillpoint and Degree of Fill

- Spillpoint: cannot be determined from a “deterministic” map

- Moving the spillpoint shallower on a “deterministic” map is really changing the degree of fill. It is not reflecting the uncertainty of the structure such as would be obtained by contouring it differently

- Moving the spillpoint deeper than the lowest closing contour on a “deterministic” map is a contradiction because the structure would spill, hence the arbitrary extrapolation of area/depth curves

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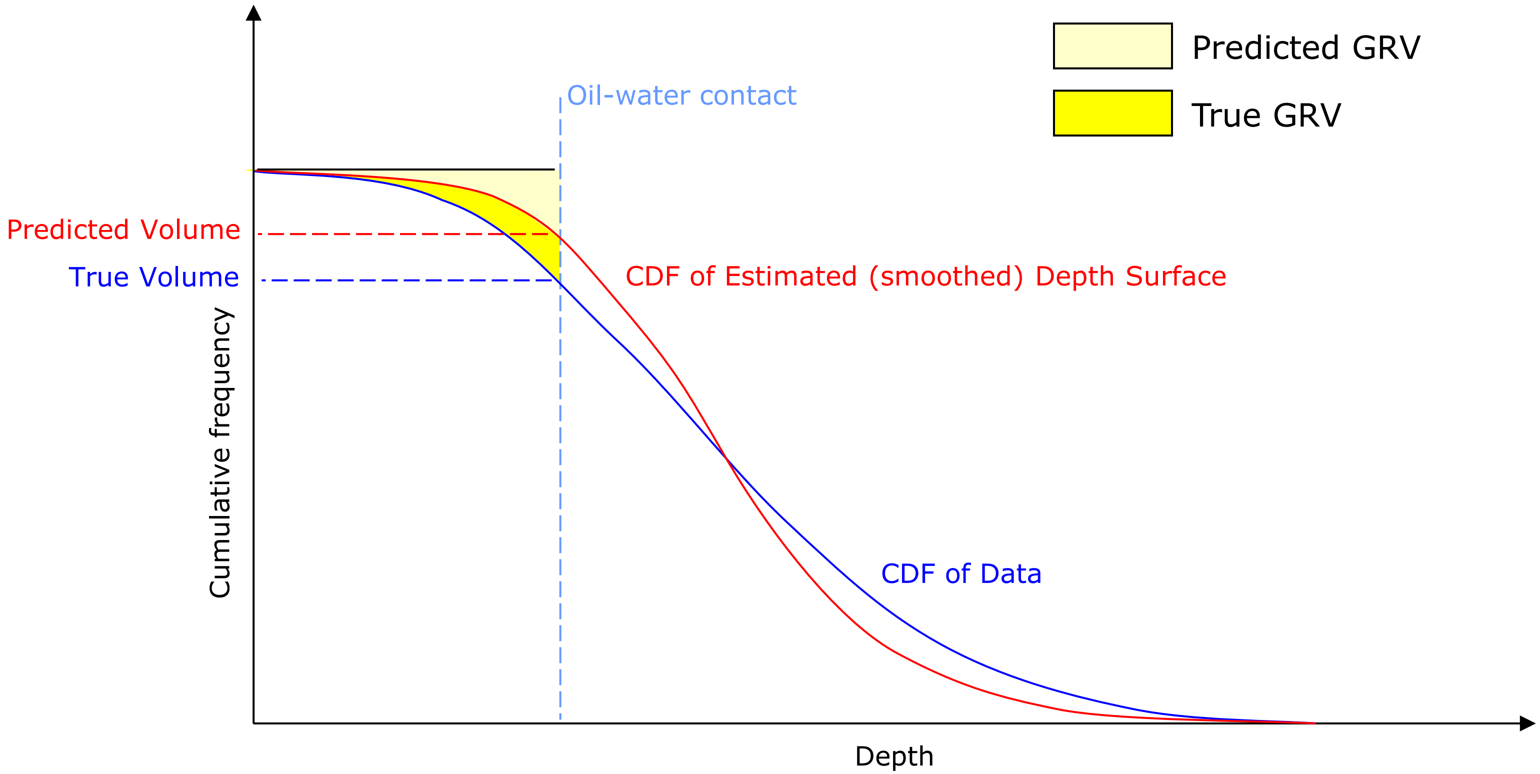
# Smoothing of the Cumulative Distribution Function (CDF)



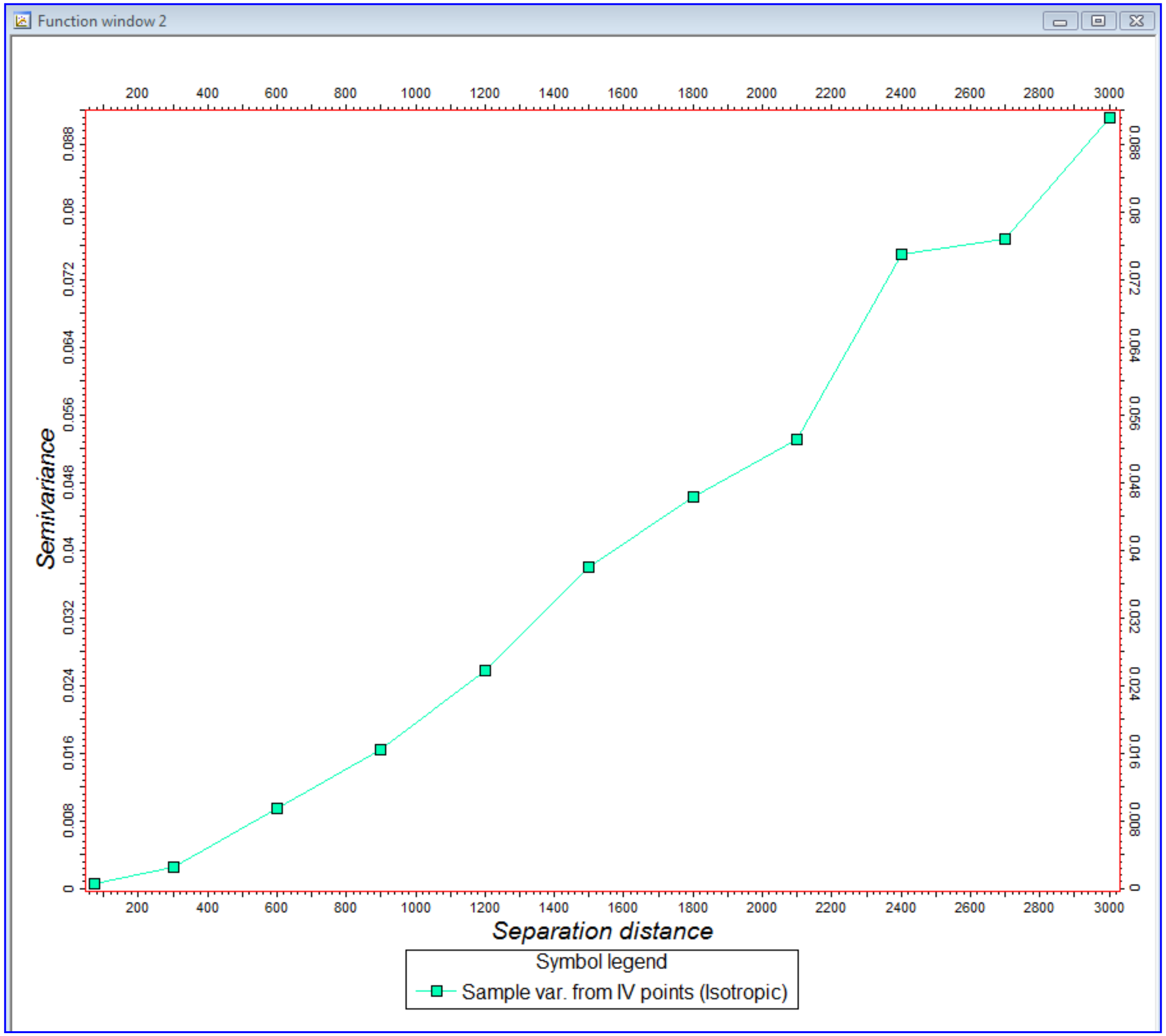

**Consequence of smoothing > Volume generally underestimated**

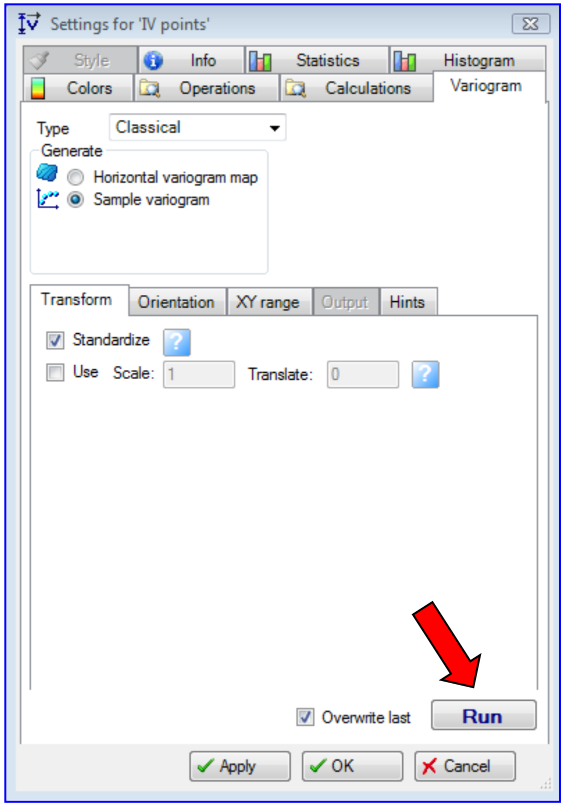
**The estimation is biased**

**Kriging is unbiased – positive and negative errors cancel out of average**

# Geostatistical Analysis (1)

## Experimental Semi-Variogram




Open the Variogram tab in the setting window of the IV points and run it. The spatial correlation of the input data is calculated.

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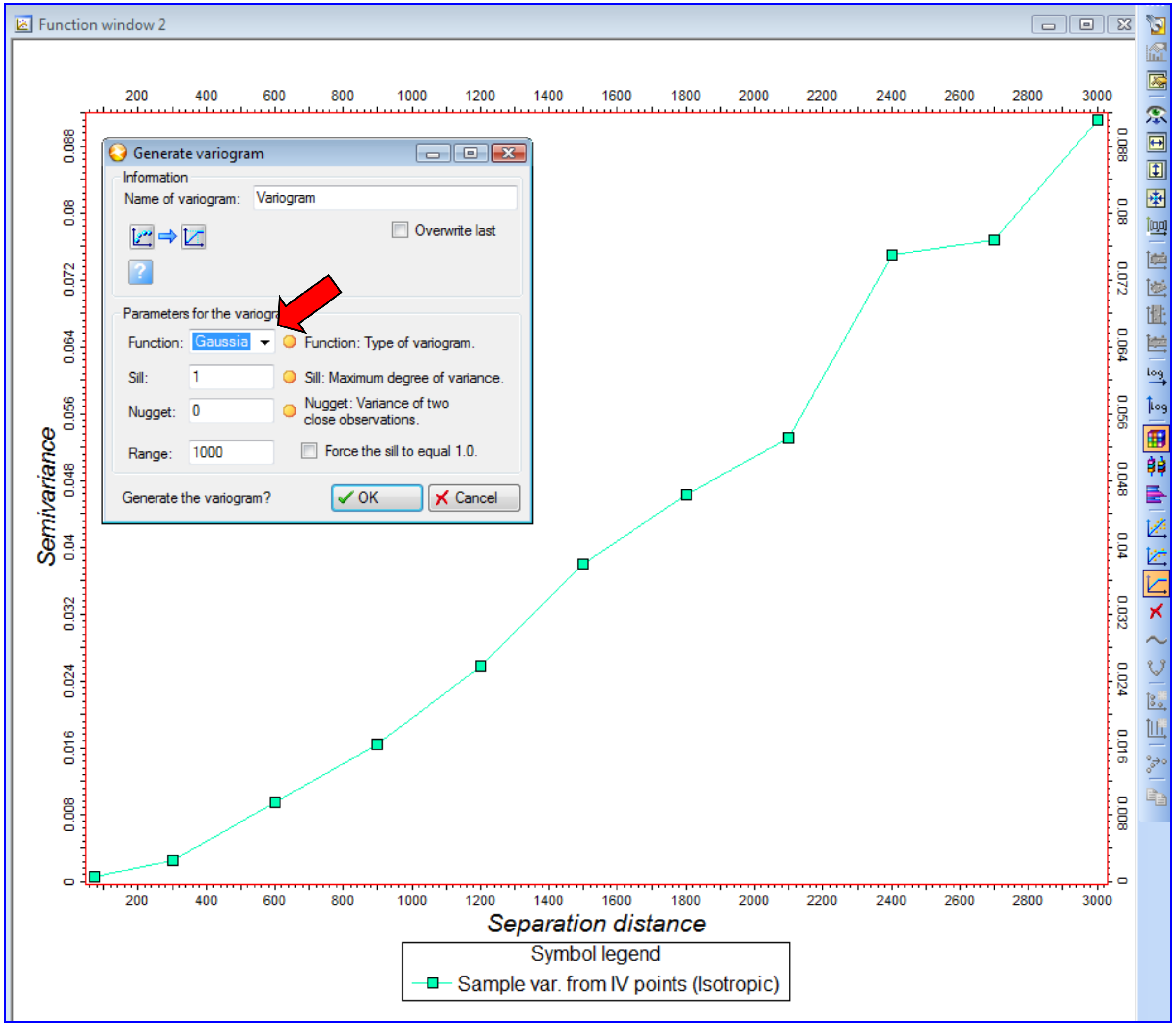
# Geostatistical Analysis (2)

## Theoretical Semi-Variogram



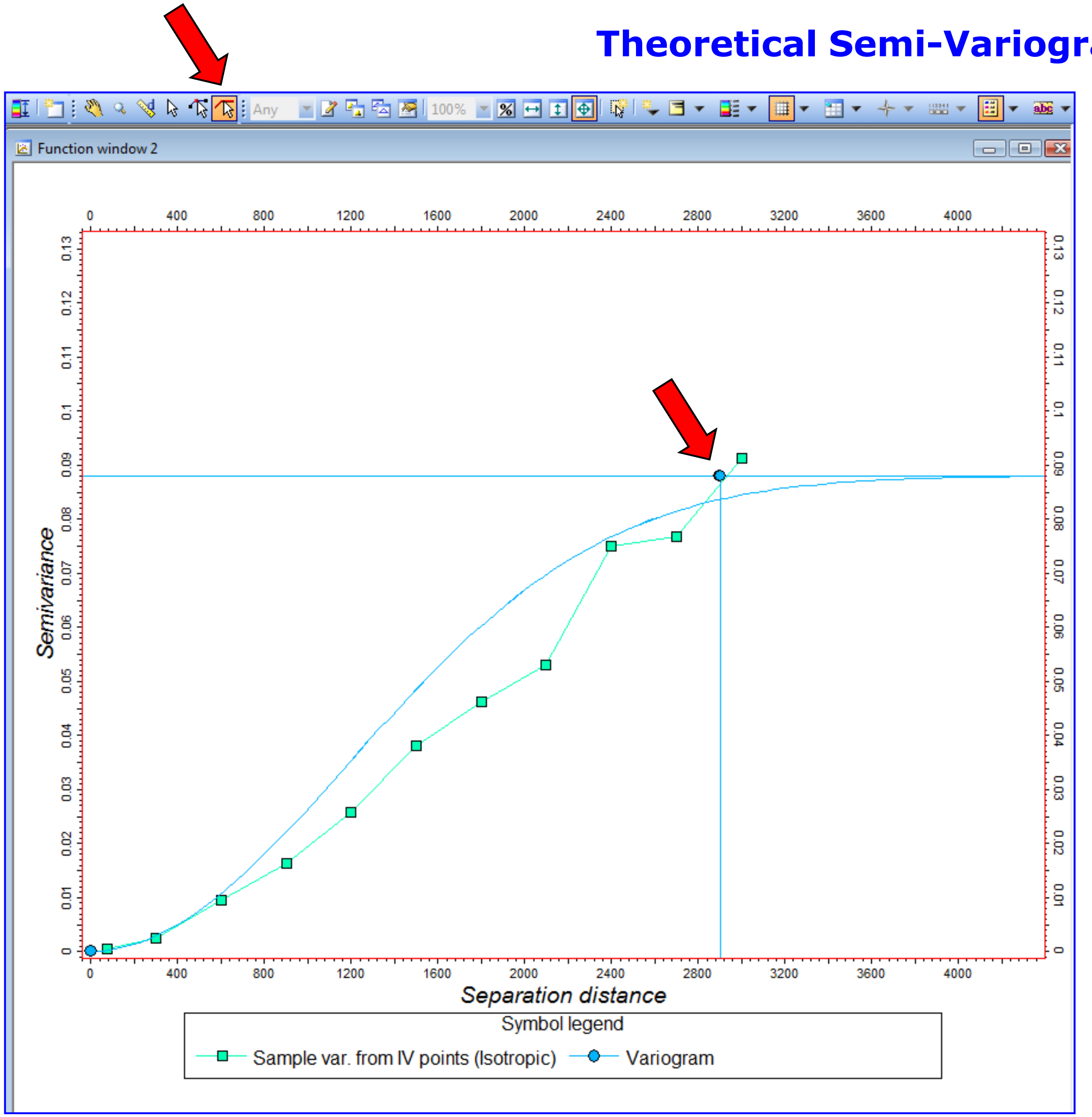

Create a NEW Variogram and set initial parameters. The main choice is between the type of Variogram:

1) Gaussian
2) Exponential
3) Spherical

Select the one that better reproduce the experimental trend.

# Geostatistical Analysis (3)

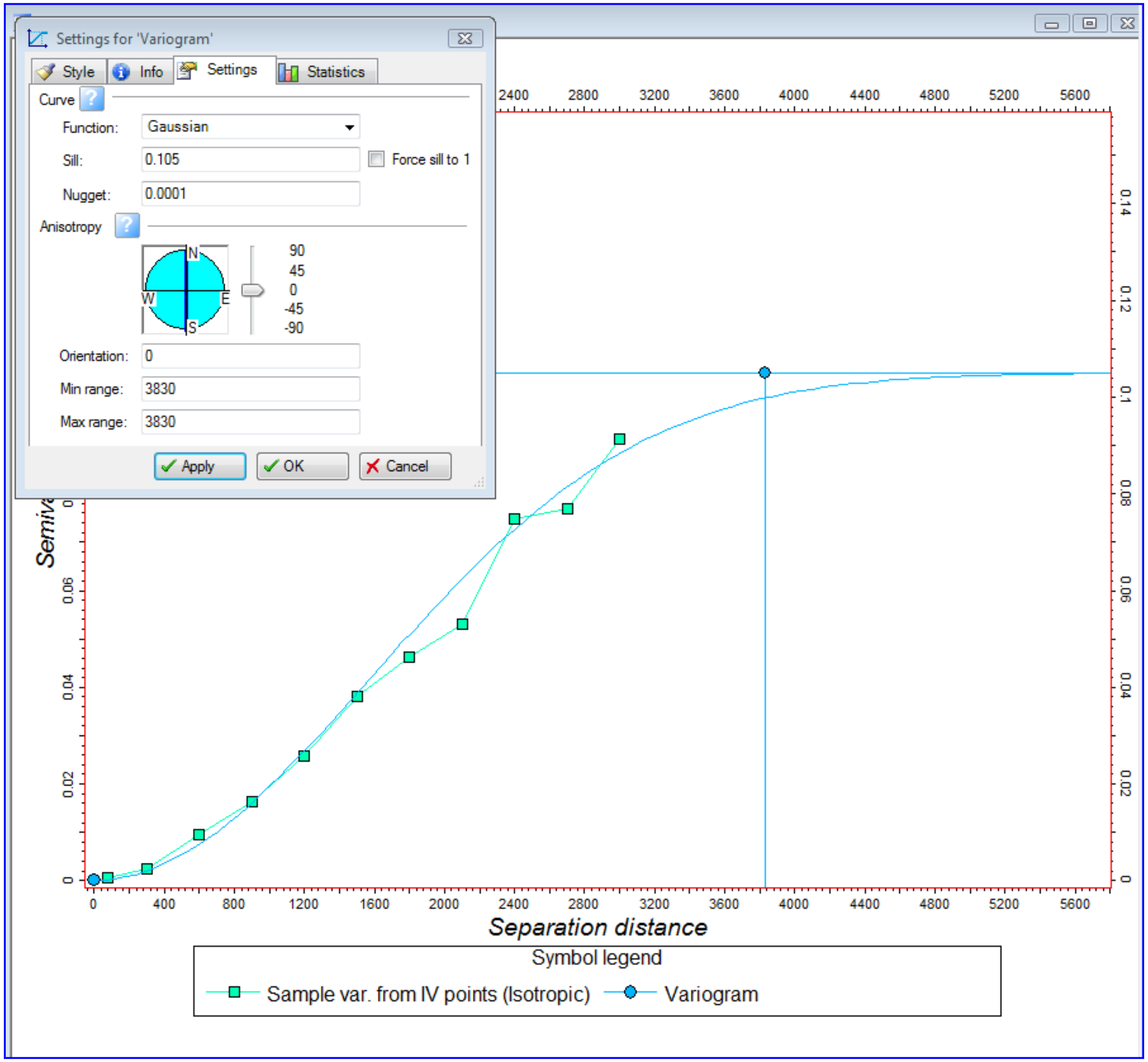
## Theoretical Semi-Variogram




Fit the theoretical Variogram to the experimental value using the tool indicated by the red arrow and drag the blue point.

# Geostatistical Analysis (4)

## Theoretical Semi-Variogram




Finalize the parameters:

1) Range
2) Sill
3) Nugget