A Probabilistic Approach to Clay-Smear Fault Seal in Hydrocarbon Migration Modeling for the Tune Field

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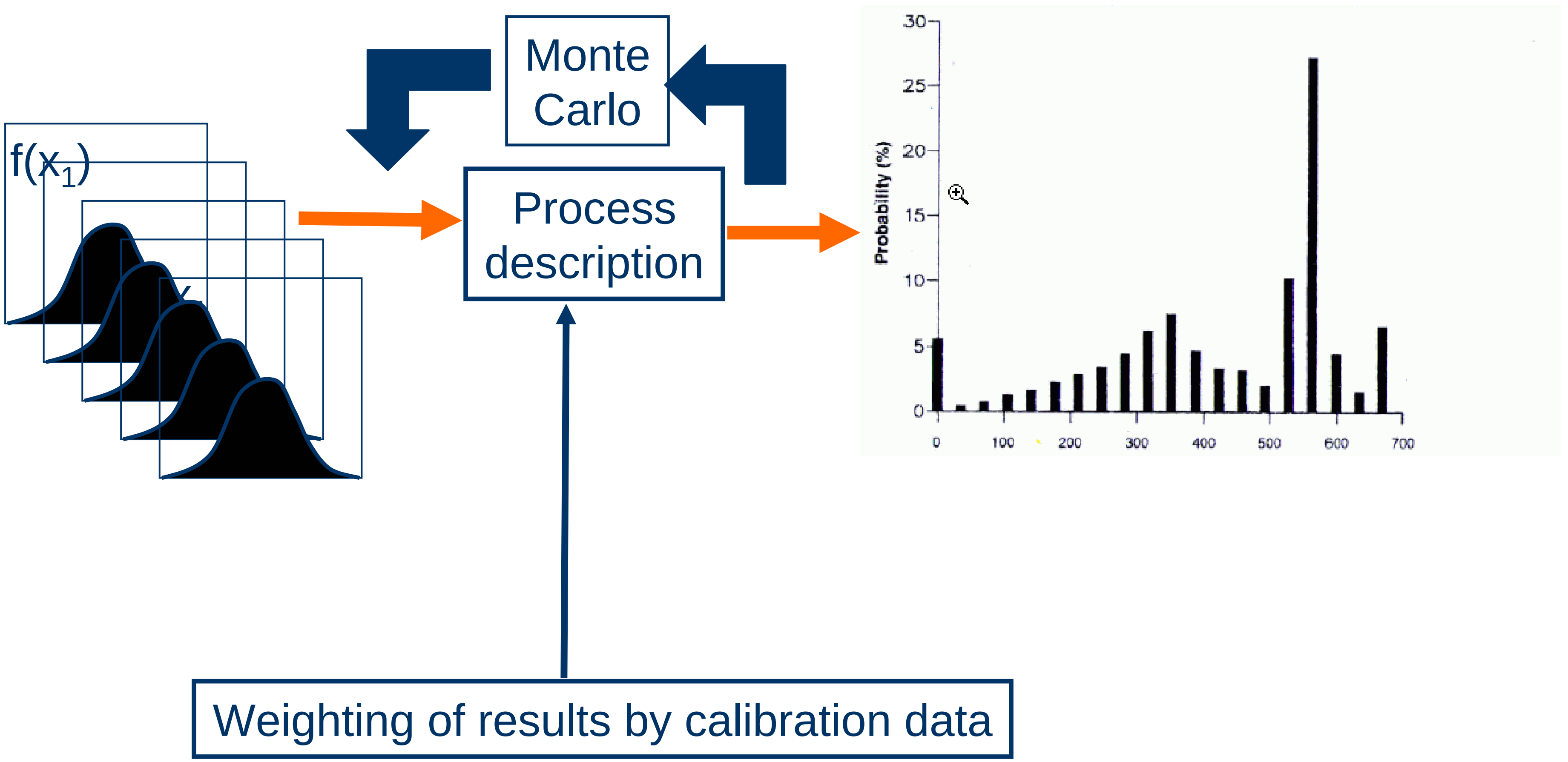
Acknowledgements

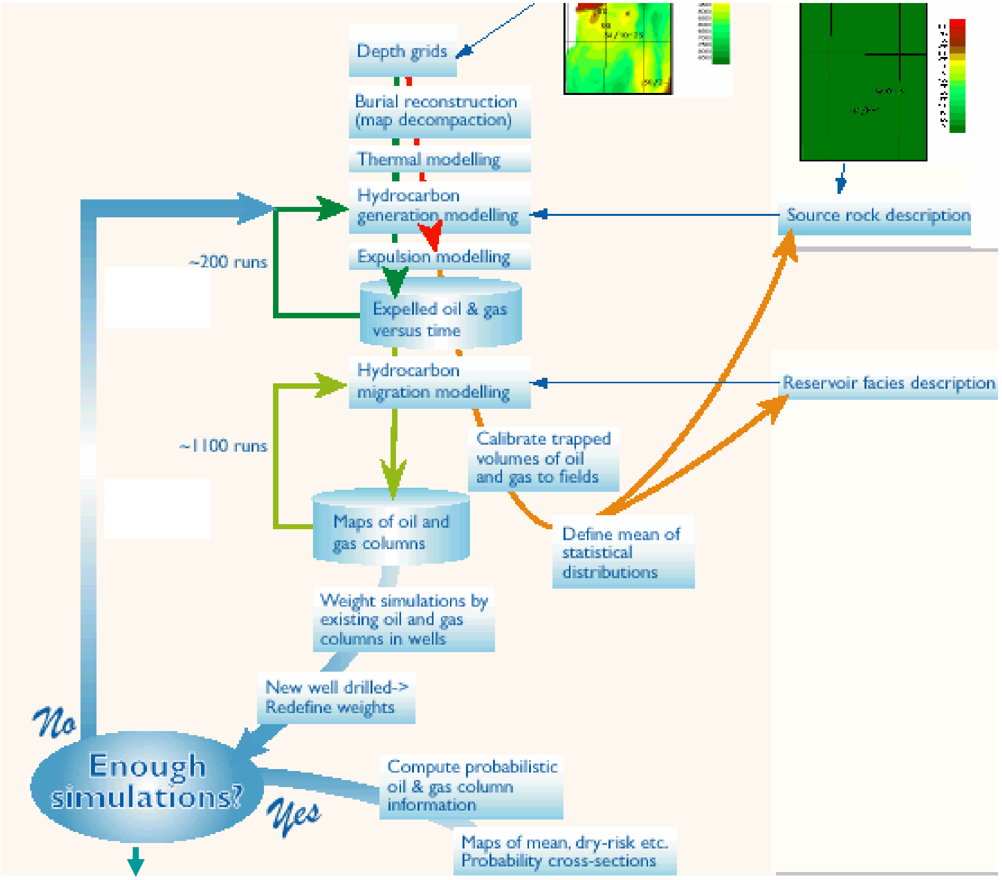
- Conrad Childs
- Ane Lothe

- SINTEF Petroleum Research
- Norsk Hydro
- EU (Infami project)

Monte Carlo simulation technique



Monte Carlo simulation scheme for basin modelling

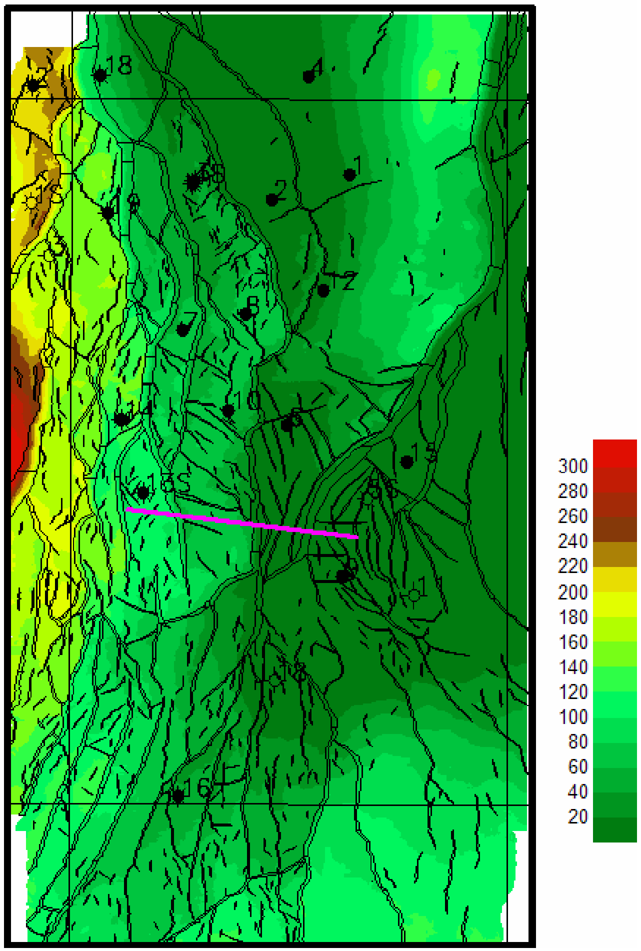


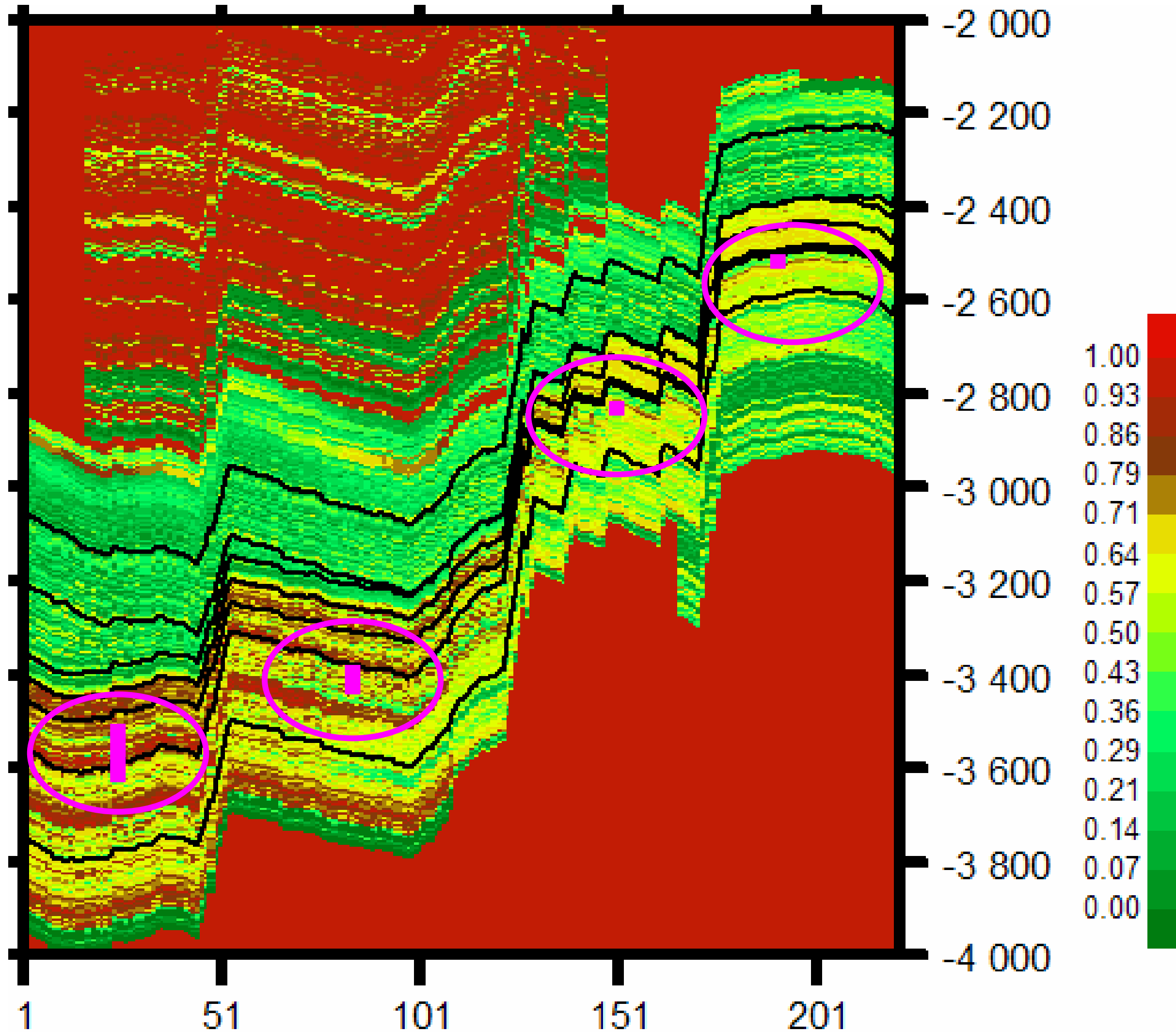
Refined
input probabilities

Secondary migration simulation procedure

- **Interpolate lithologies at 1 m vertical resolution from well-logs.**
- For fault segment:
  - SGR(x,y)=f(throw(x,y) , lithology(x,y))
- For every time-step and fault segment:
  - Pe(x,y)=f(SGR, burial_depth, faulted_depth)
  - Column_seal=f(Pe(x,y), density, hc_phase)
  - Use column_seal in flow-calculations.

Interpolation of lithologies onto fault planes from well-logs

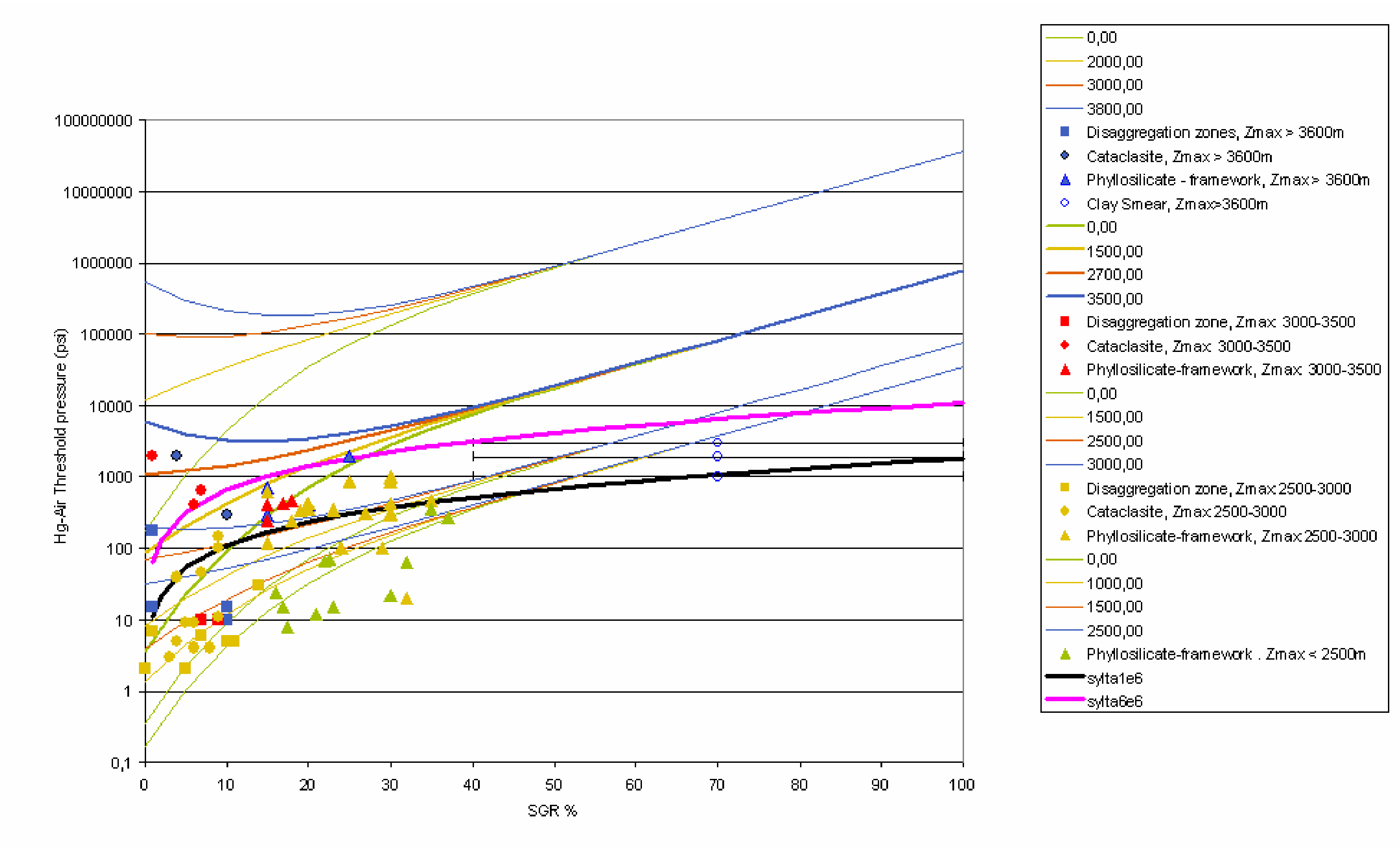




Secondary migration simulation Procedure

- Interpolate lithologies at 1 m vertical resolution from 18 well-logs.
- For fault segment:
  - SGR(x,y)=f(throw(x,y) , lithology(x,y))
- For every time-step and fault segment:
  - **Pe(x,y)=f(SGR, burial_depth, faulted_depth)**
  - Column_seal=f(Pe(x,y), density, hc_phase)
  - Use column_seal in flow-calculations.

Sperrevik et al, 2002: Pe=f(SGR,burial_depth,faulted_depth)



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Clay-smear Monte Carlo in Tune:

- Variables:
  - 4 clay-smear variables
  - 1 clay-smear up-scaling variable
  - 4 expulsion variables
  - Gas leakage rate
- Uniform distributions
- 3200 simulation runs

Monte Carlo input distributions:

- <infami-depth='500. {STAT 1000 UNIFORM:1000}‘

- <infami-missing='0.0   {STAT 500 UNIFORM:500}‘   &   0
- <infami-maxsgr='0.5   {STAT 0.5 UNIFORM:0.2}'
- <infami-diagenesis='9000. {STAT 6000 UNIFORM:2000}‘
- <pe-scale=’5.5 {STAT 6 UNIFORM 5}

- <leak-gasrate='0.02 {STAT 0.05 UNIFORM:0.049}'
- <expgas='1.00 {STAT 0.7 UNIFORM:0.3}'
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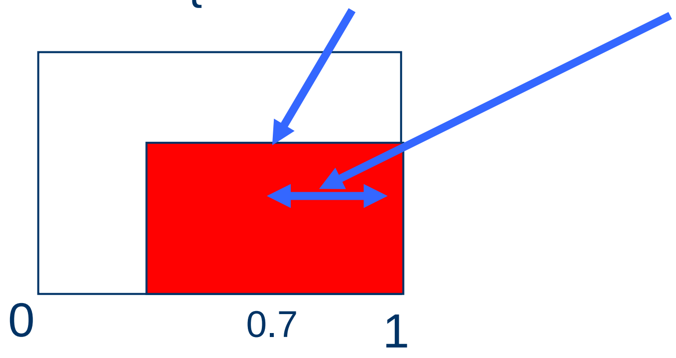
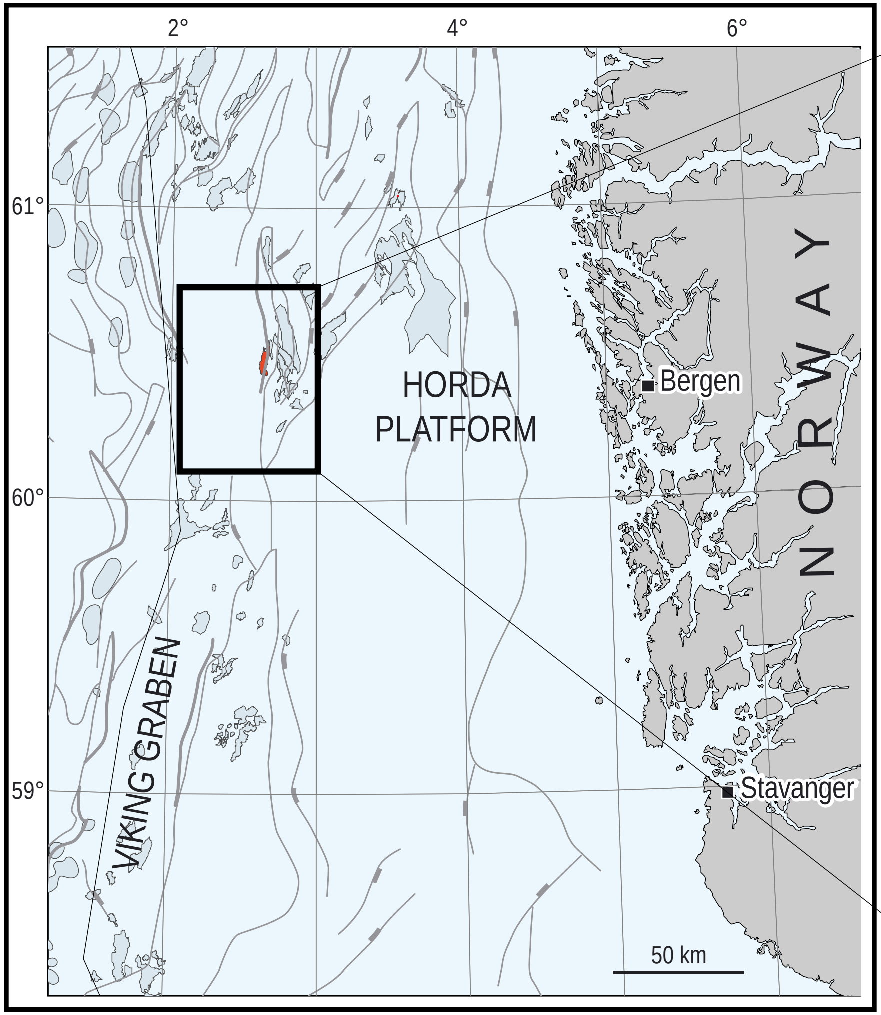
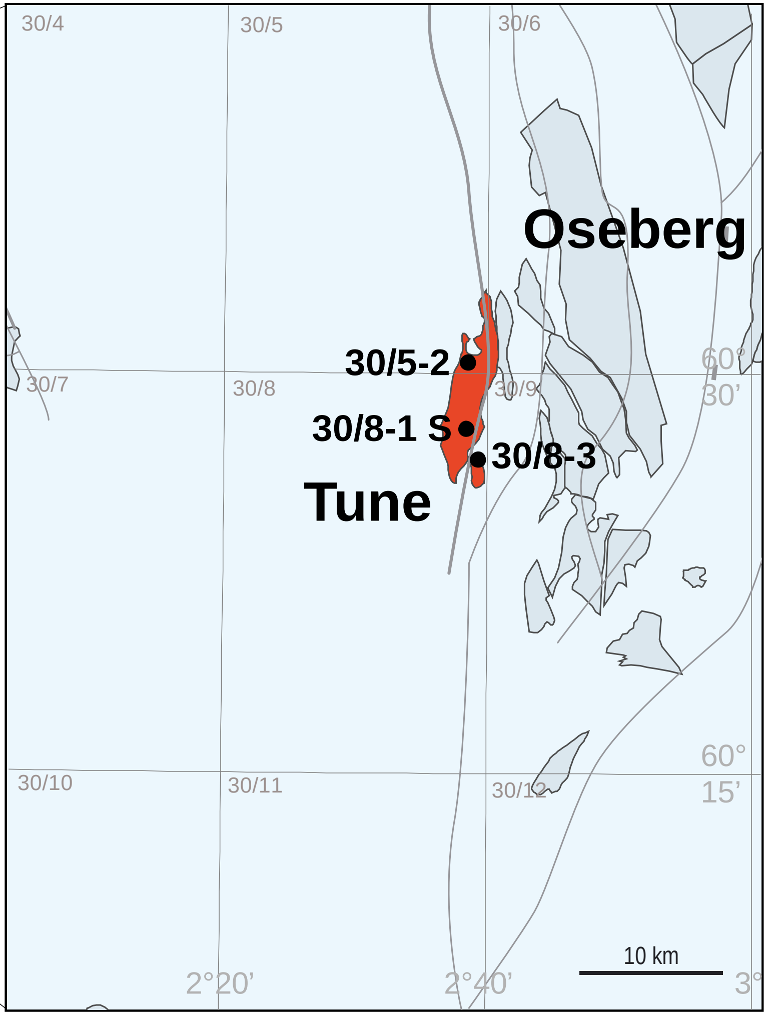
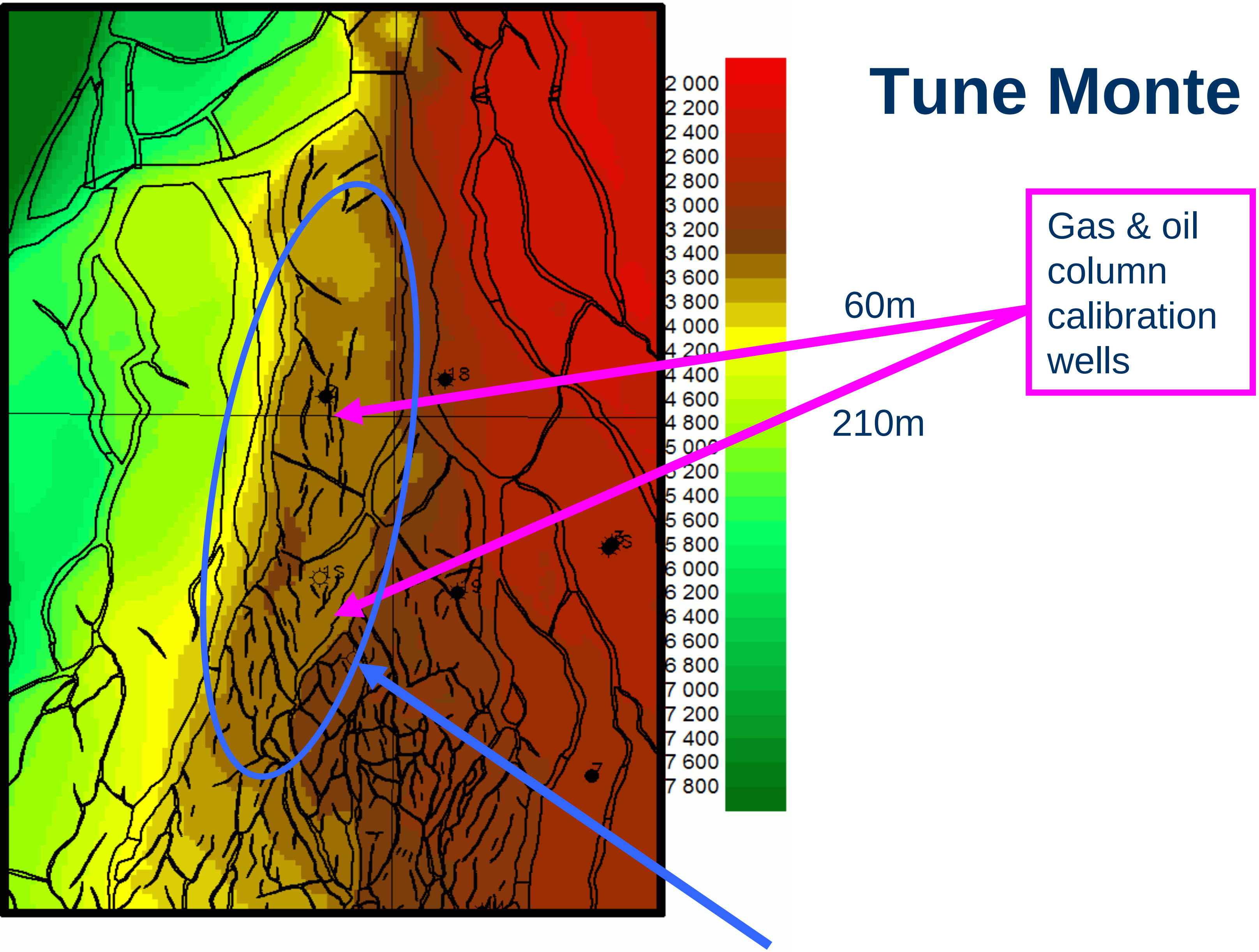


Tune Field study area





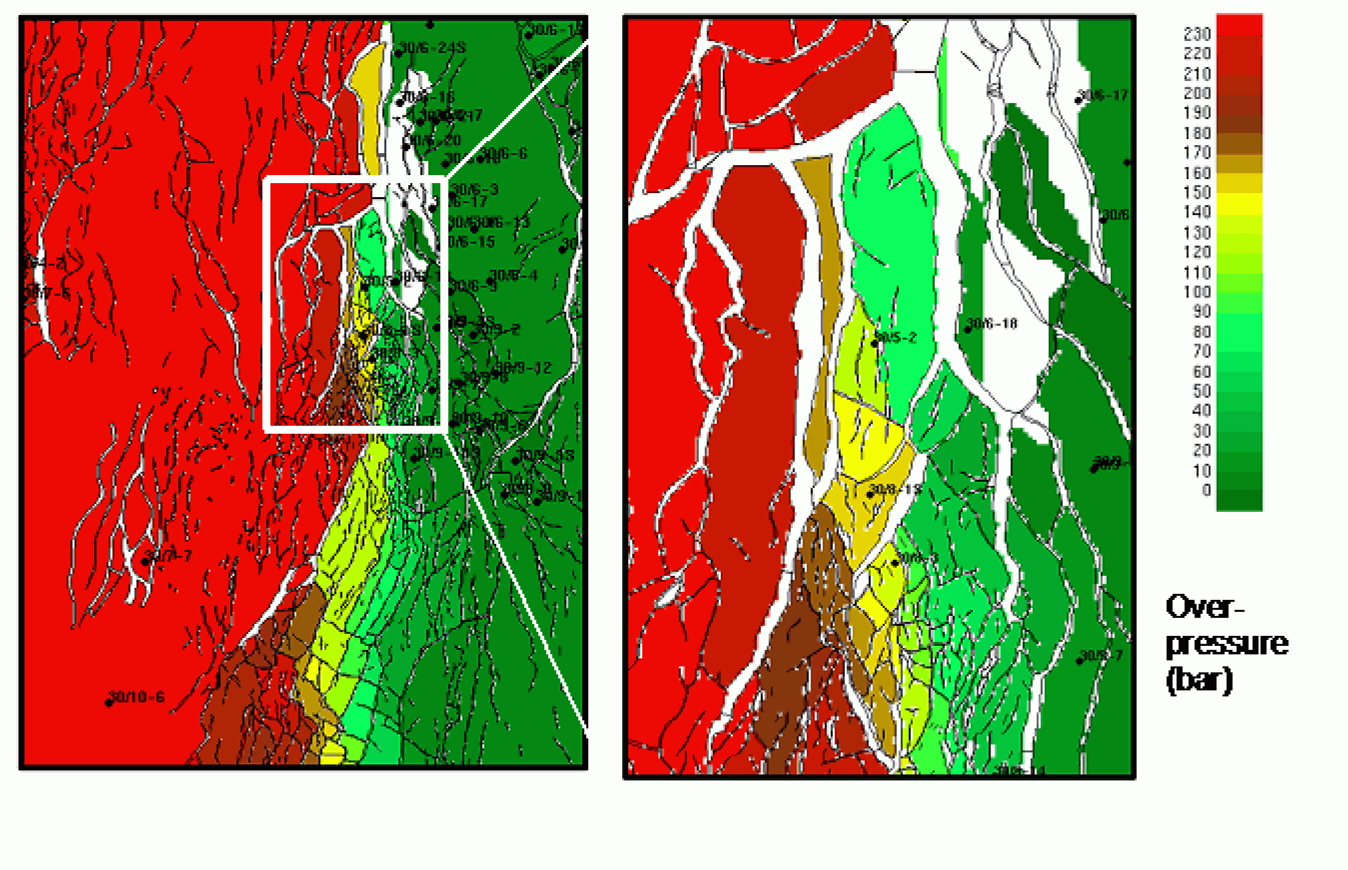
Tune Monte Carlo



Tune, case=1105-1435, ages 200-168 Ma , 2003 Sep

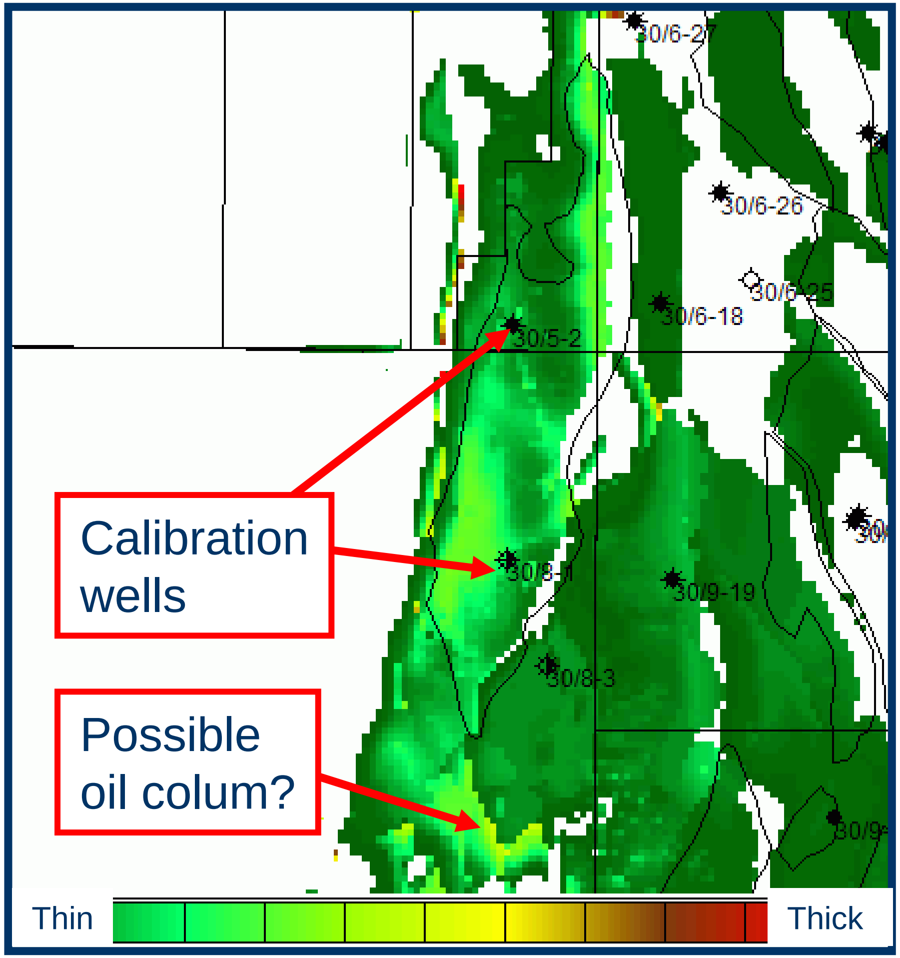
DEPTH at 0 Ma

Pressures from Lothe et al. (*)

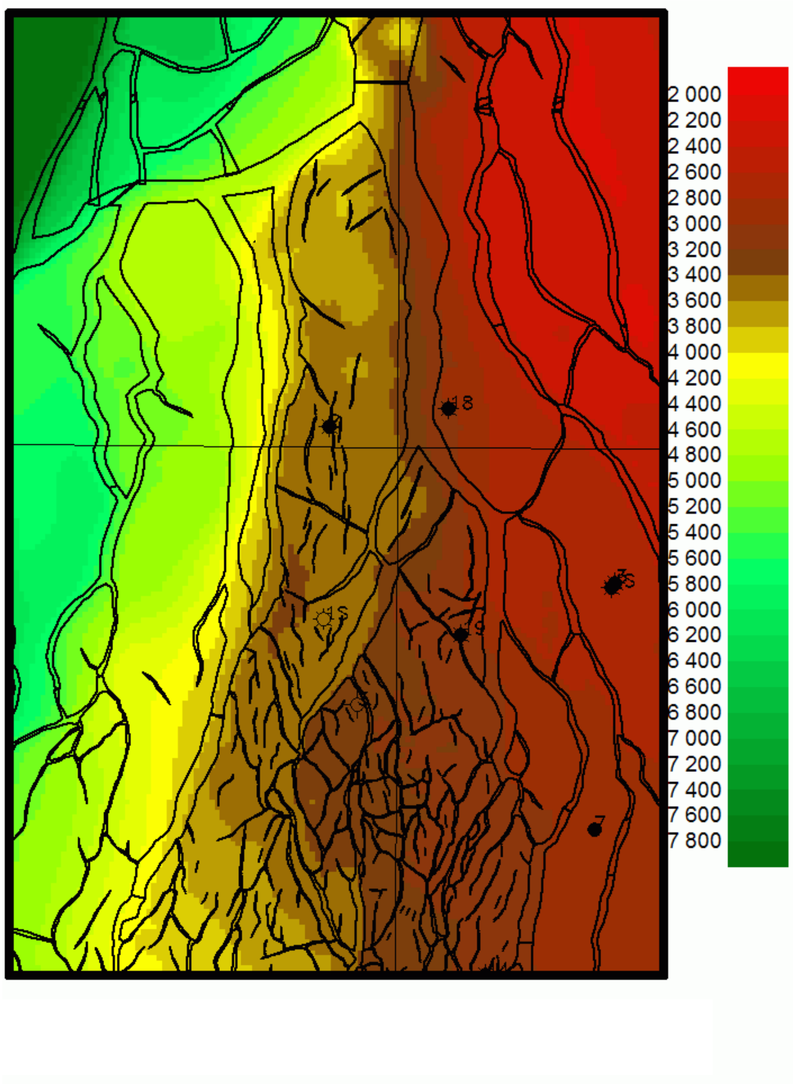


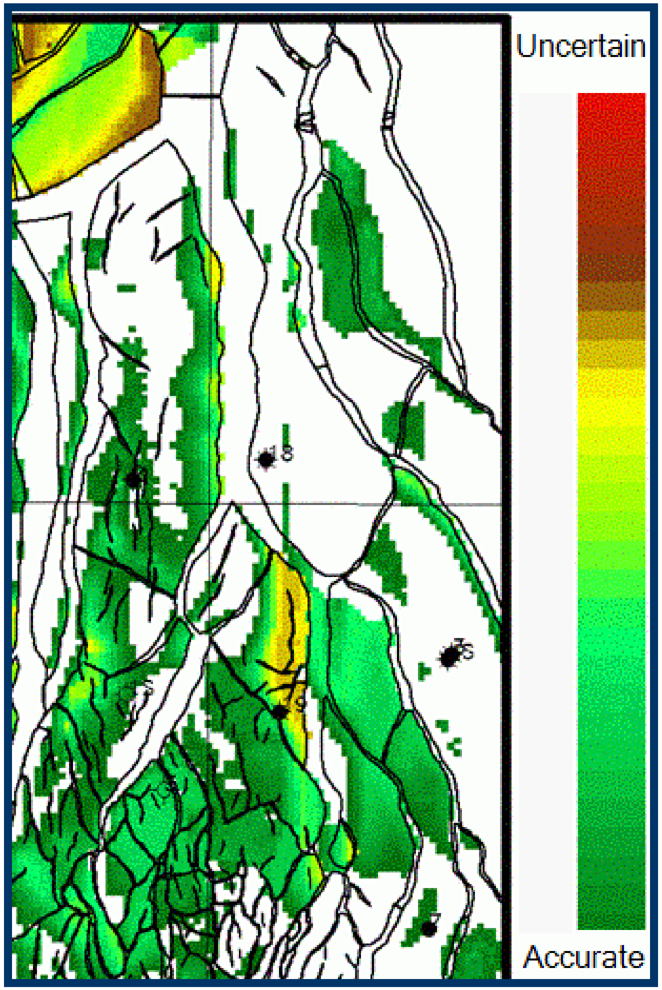
*: poster presented at the AAPG international conference in Paris, 2005.

Most likely oil columns modelled



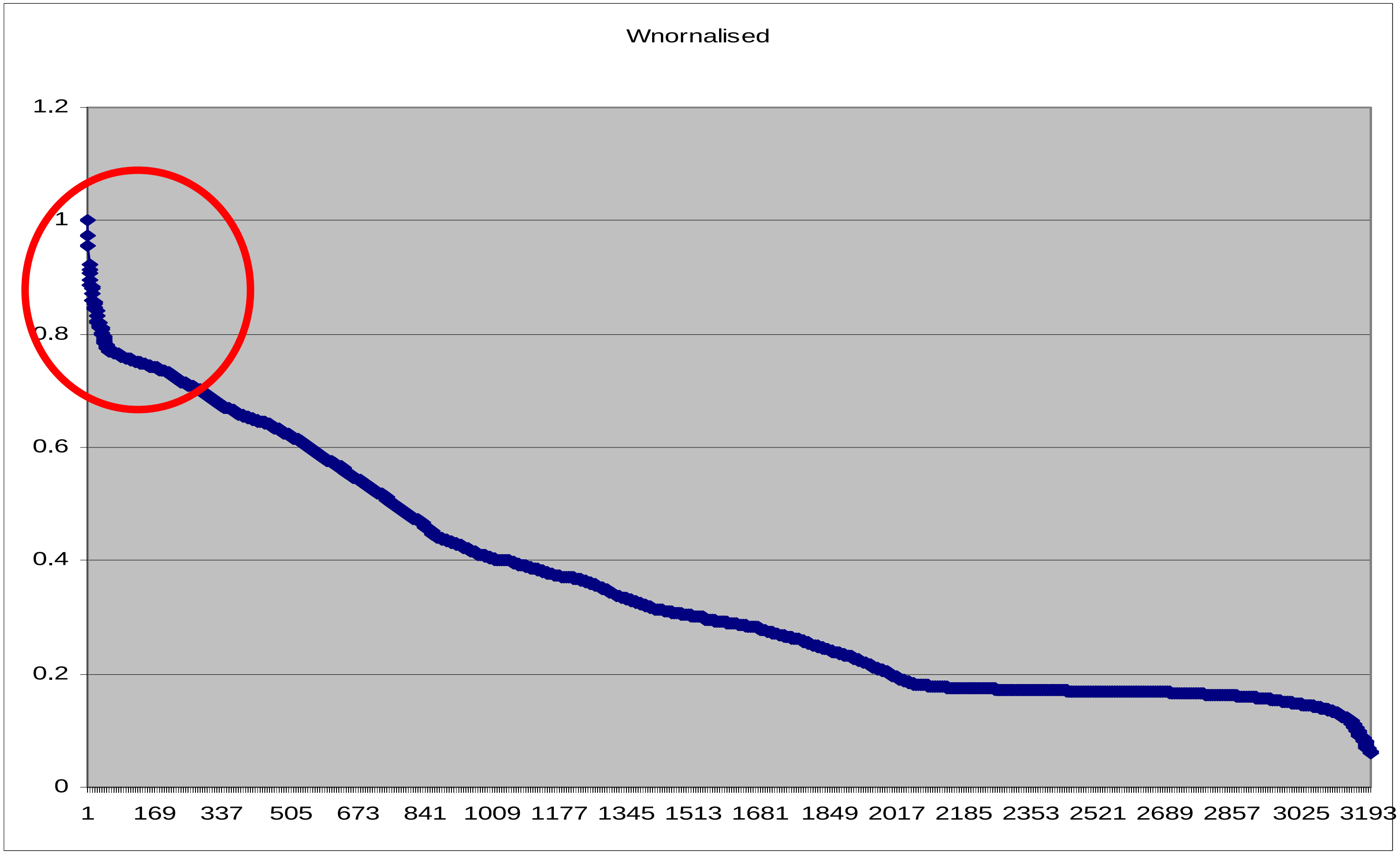
Tune Monte Carlo uncertainties



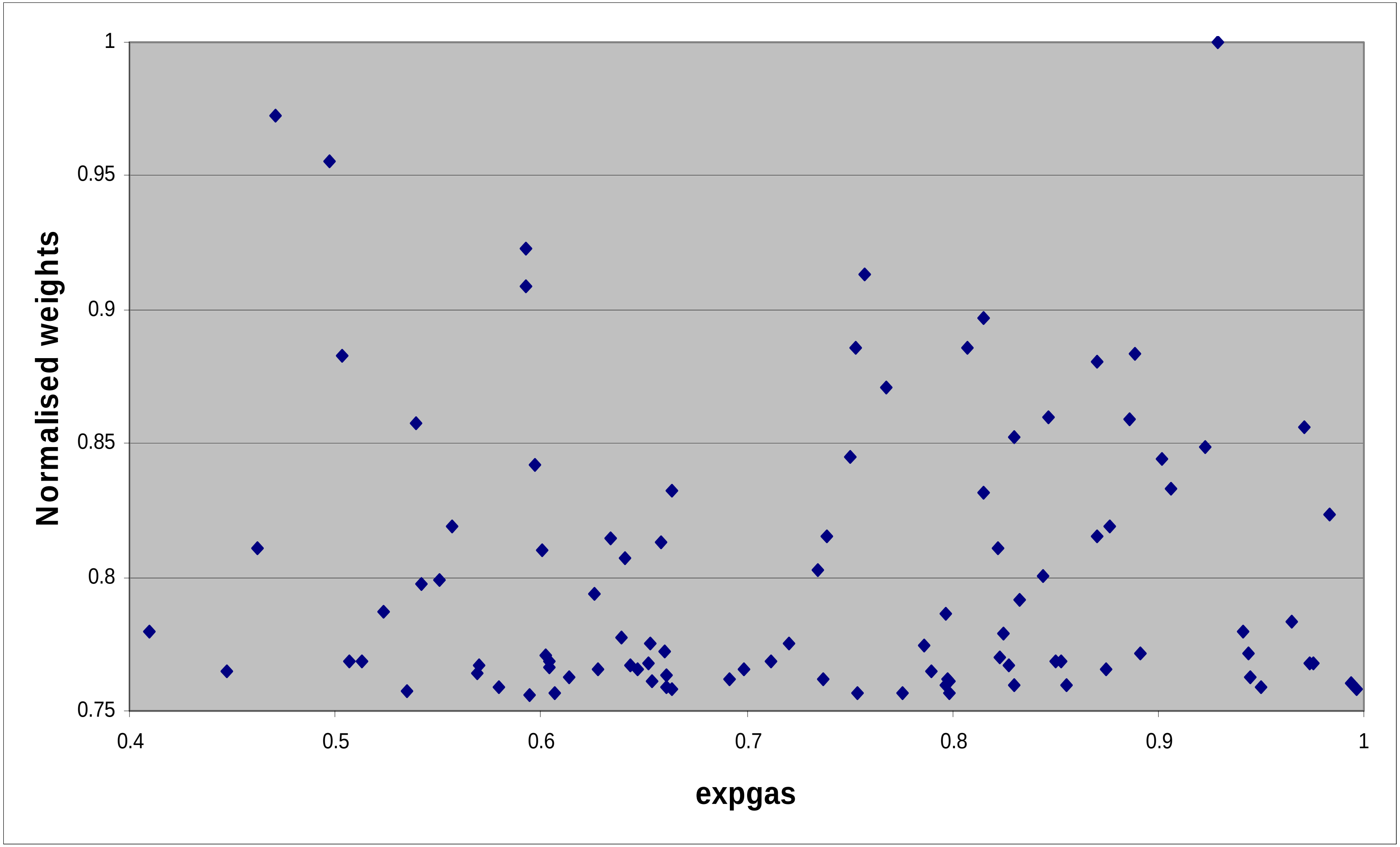


Oil column standard deviation (m)

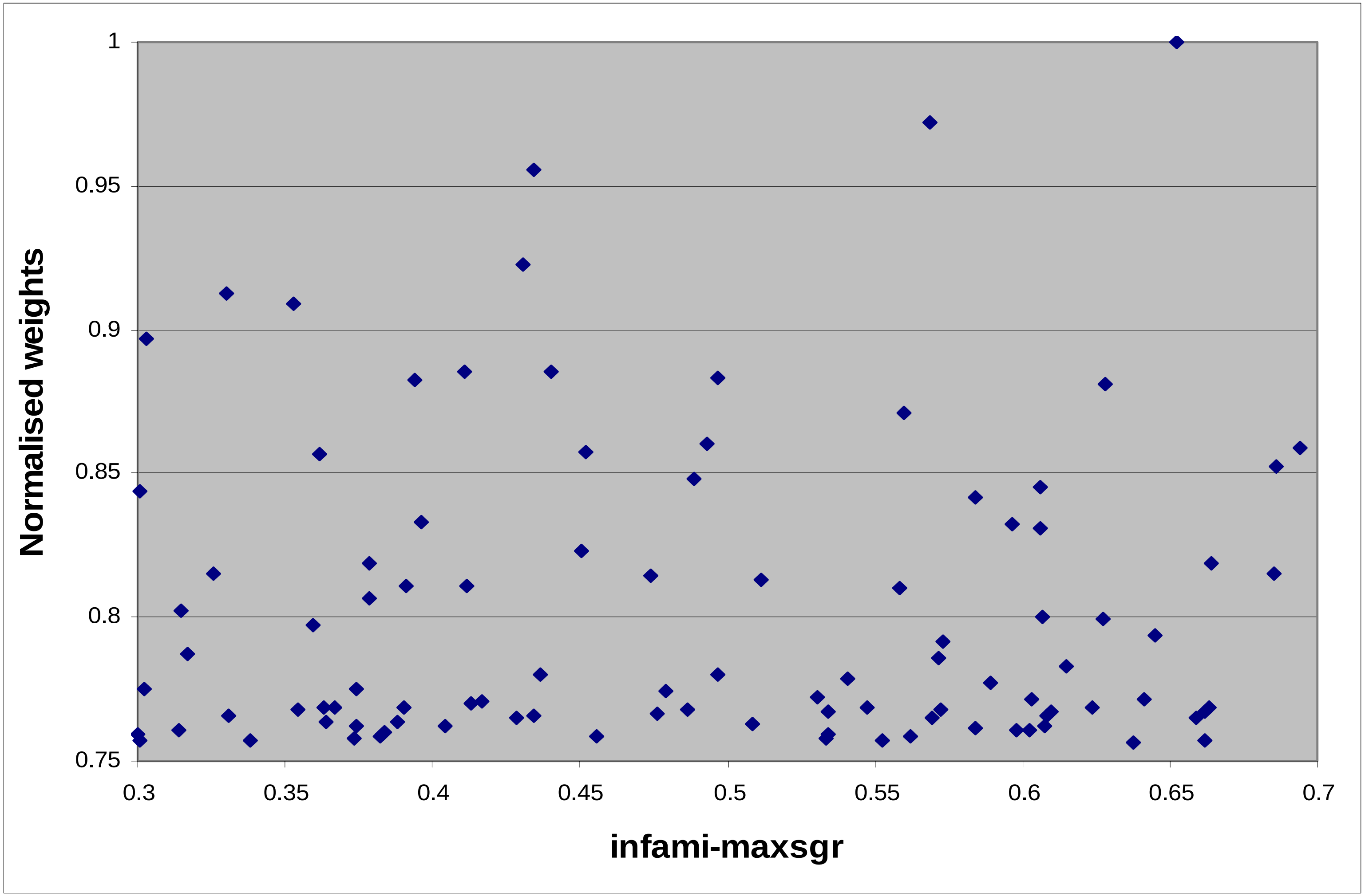
Weights (normalized) distribution



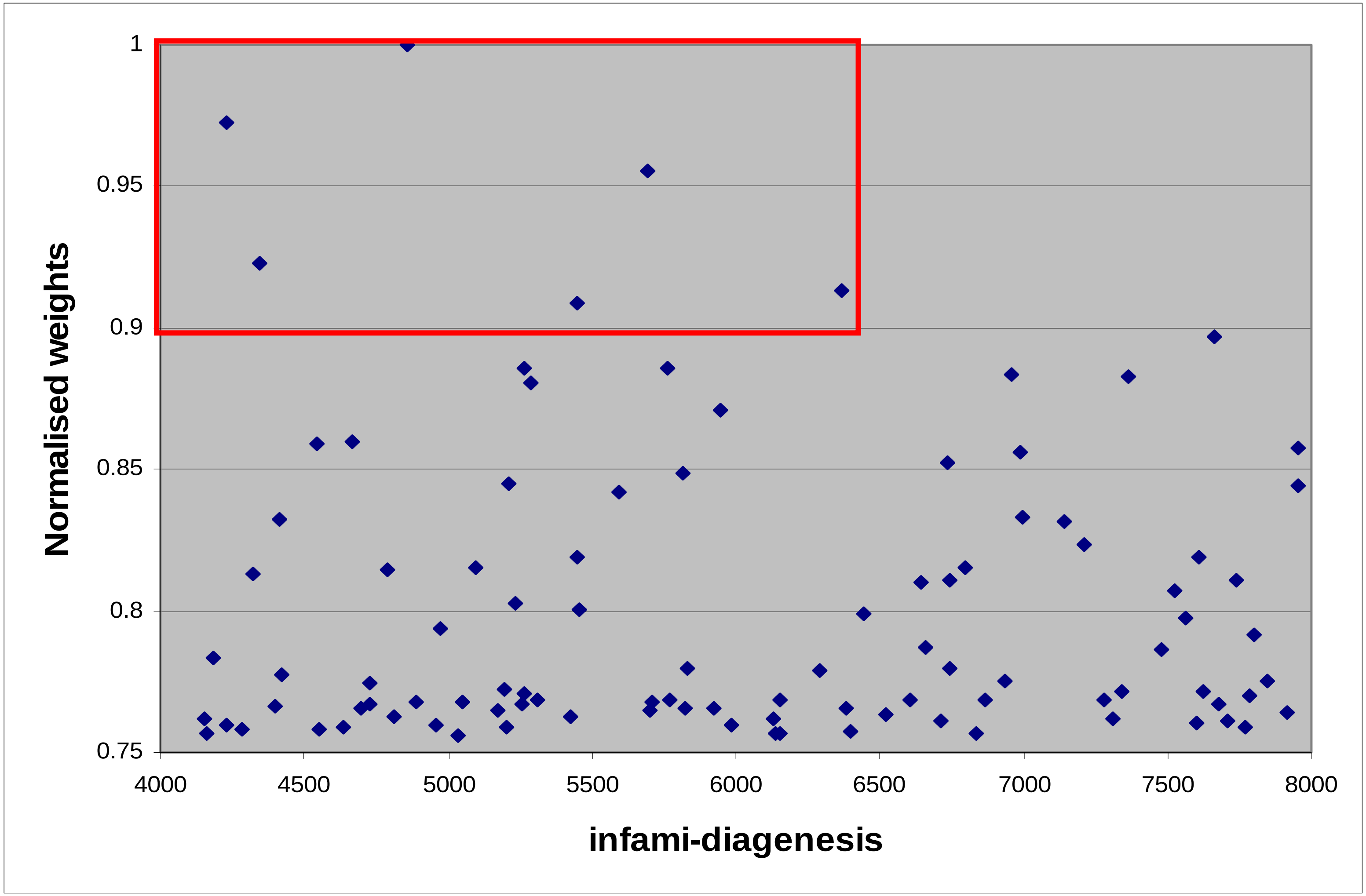
Variable distribution for best 100 runs



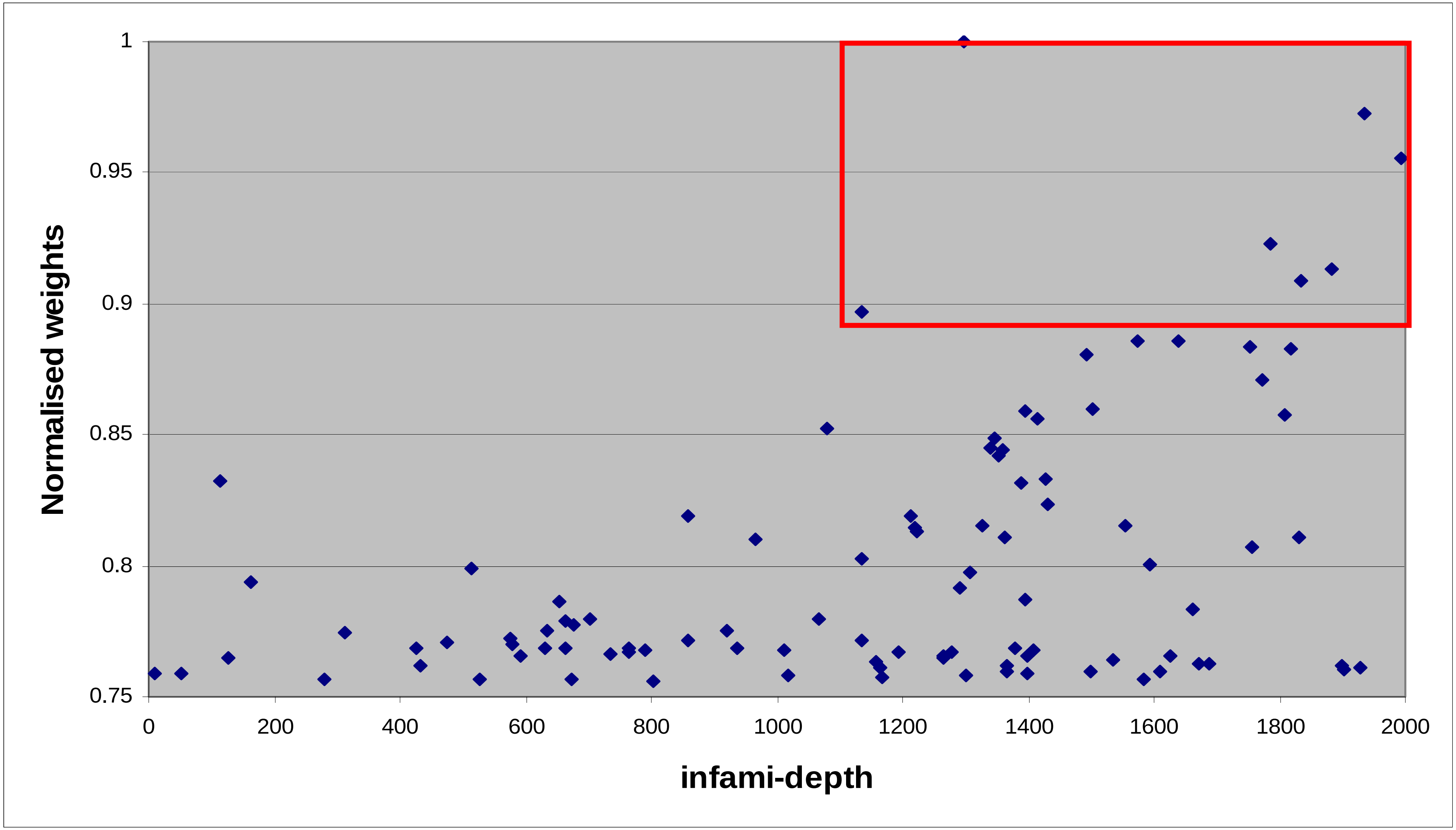
Maxsgr distribution for best 100 runs



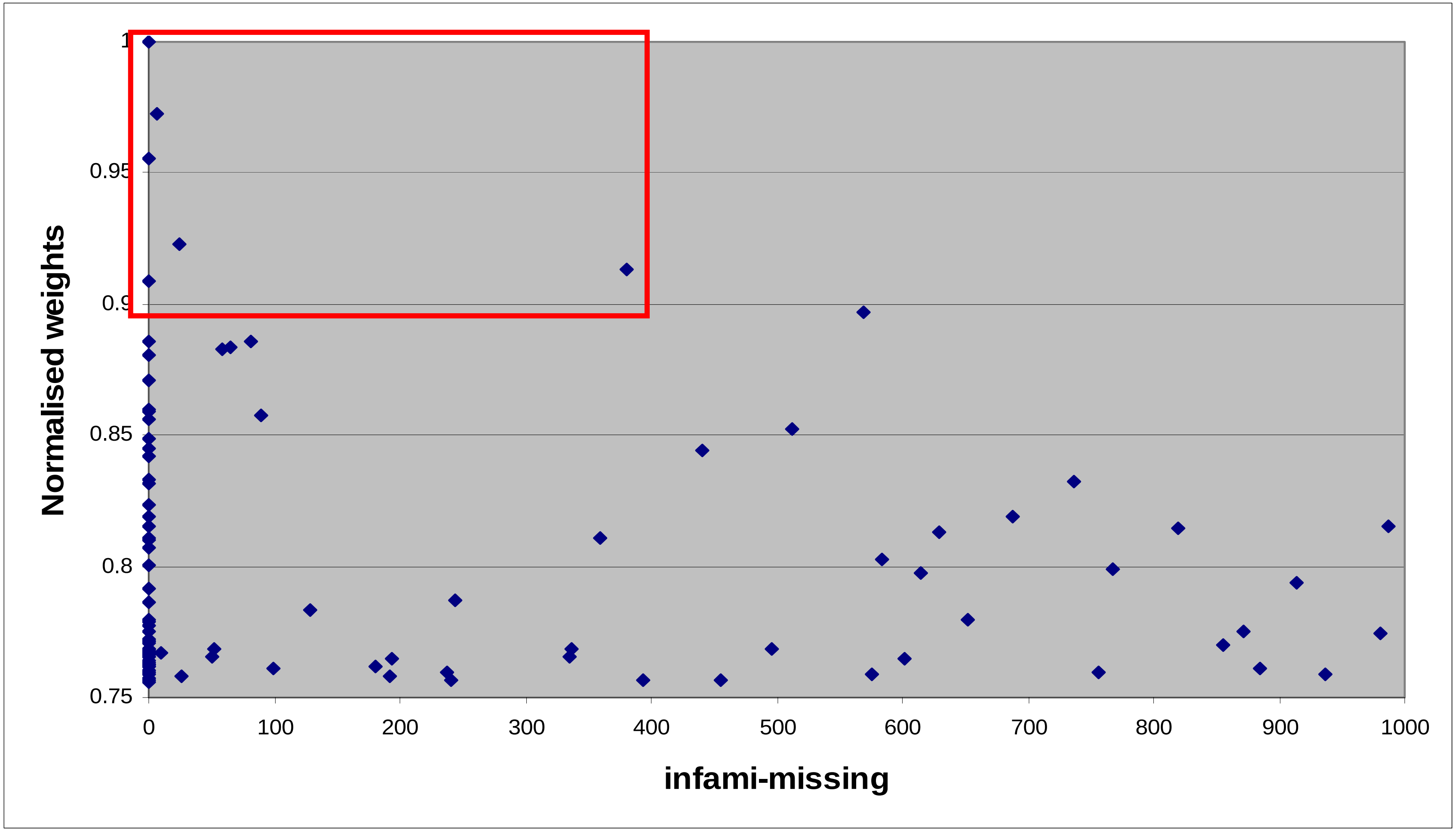
Diagenesis distribution for best 100 runs



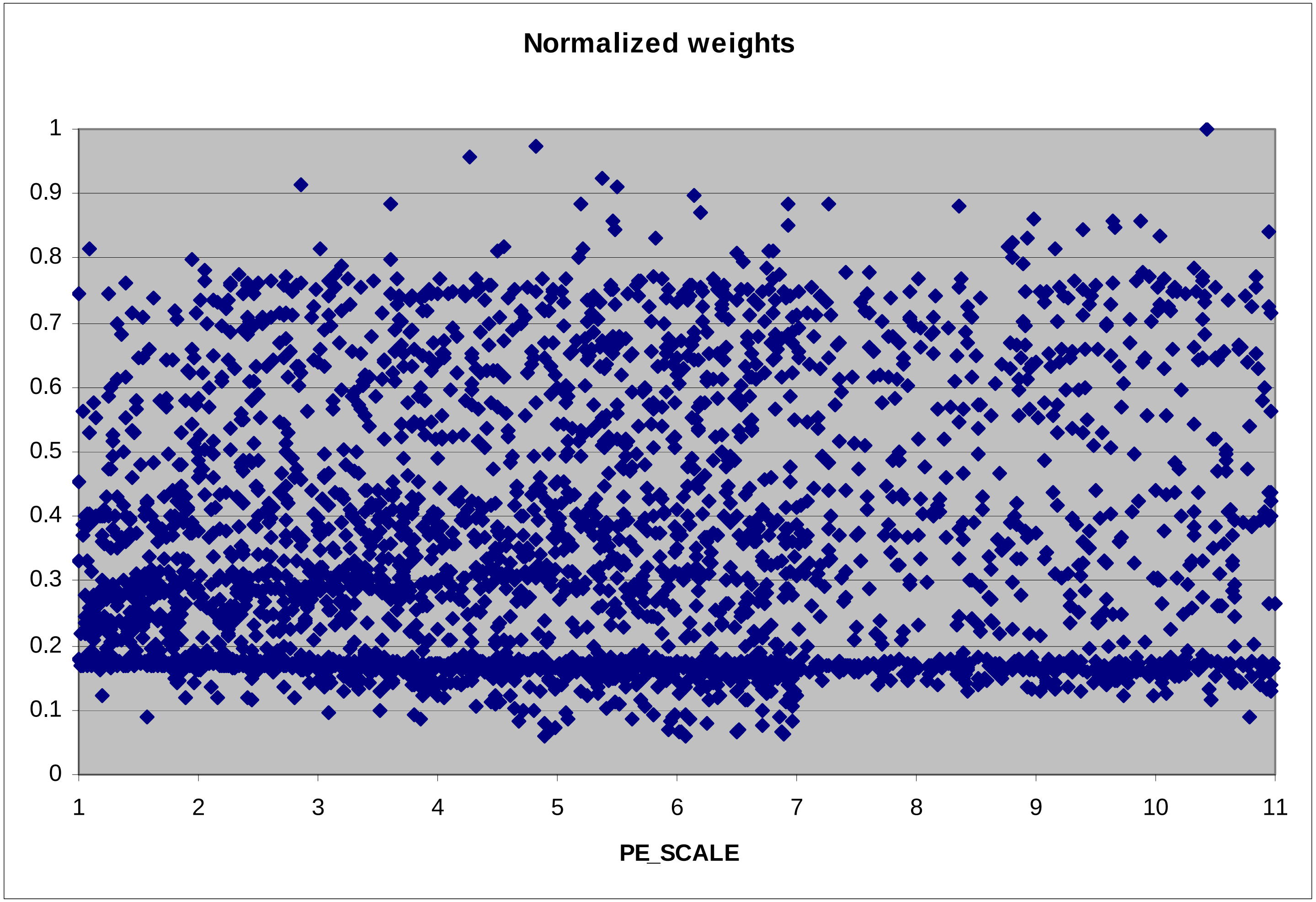
Infami-depth distribution for best 100 runs



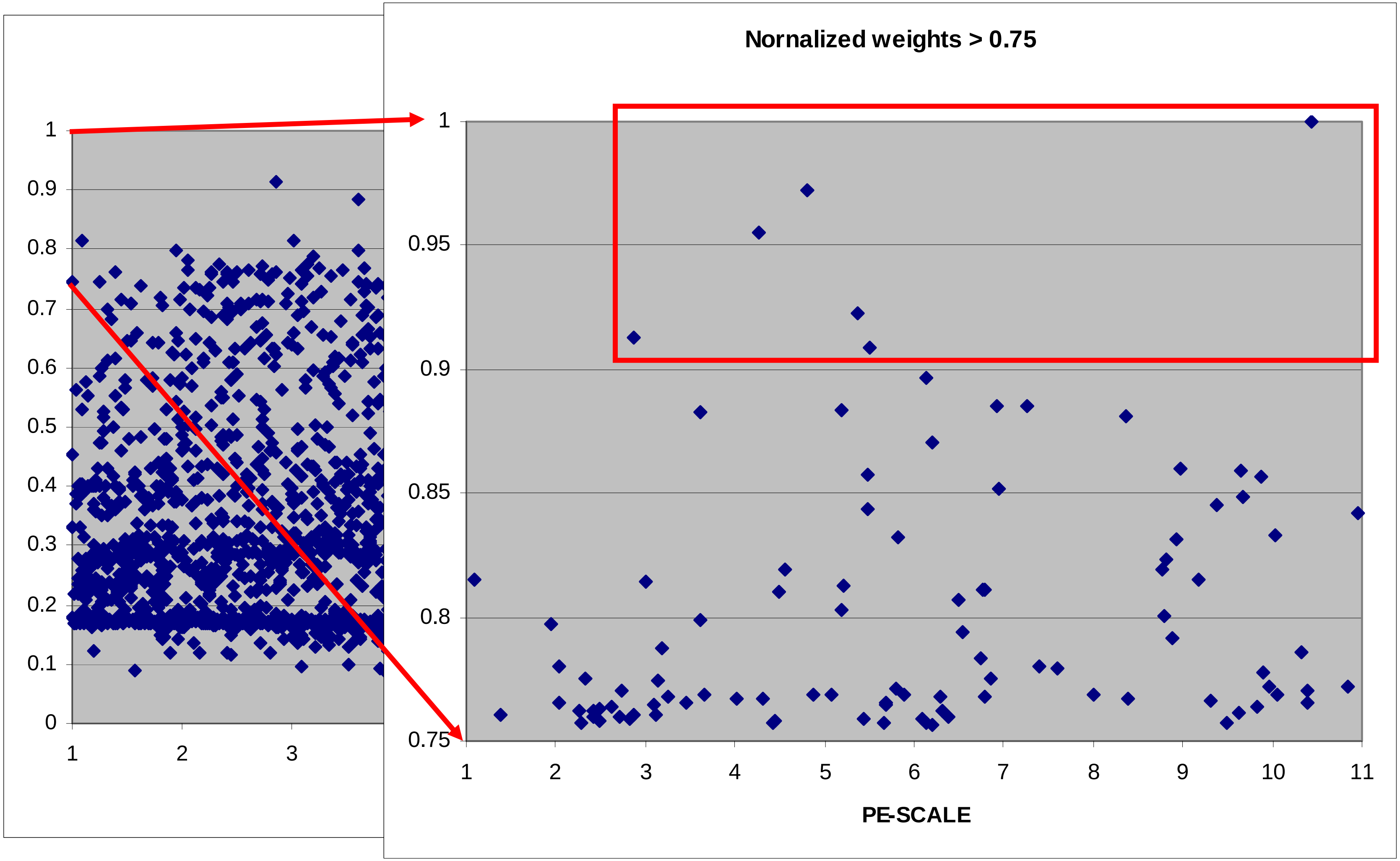
Missing distribution for best 100 runs



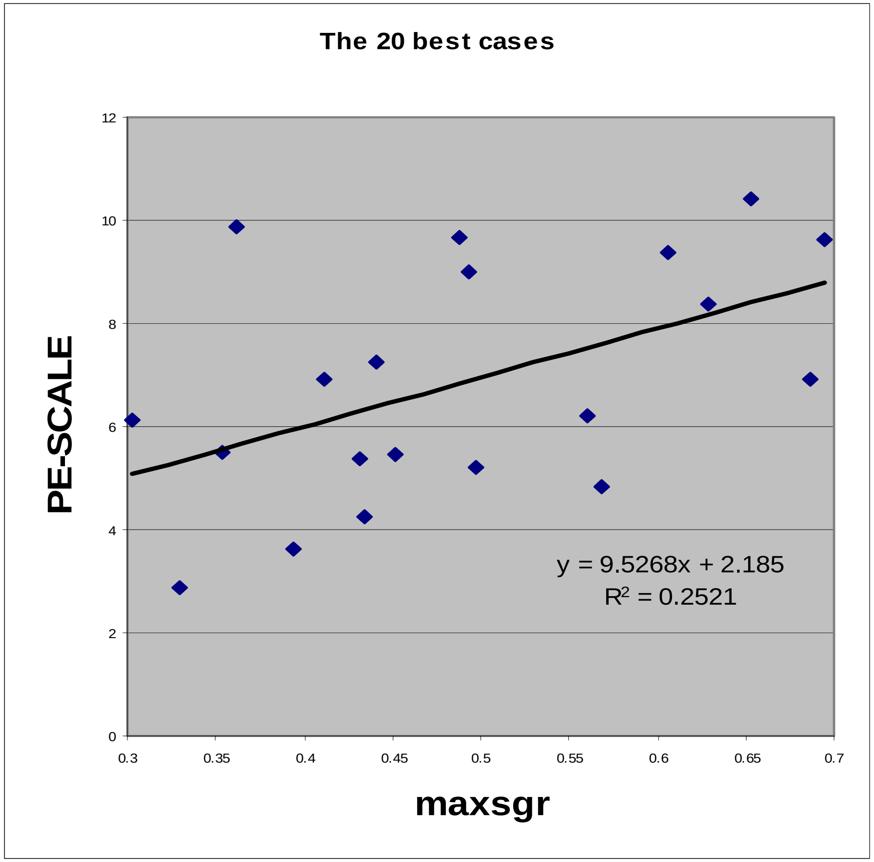
Pe-scale distribution

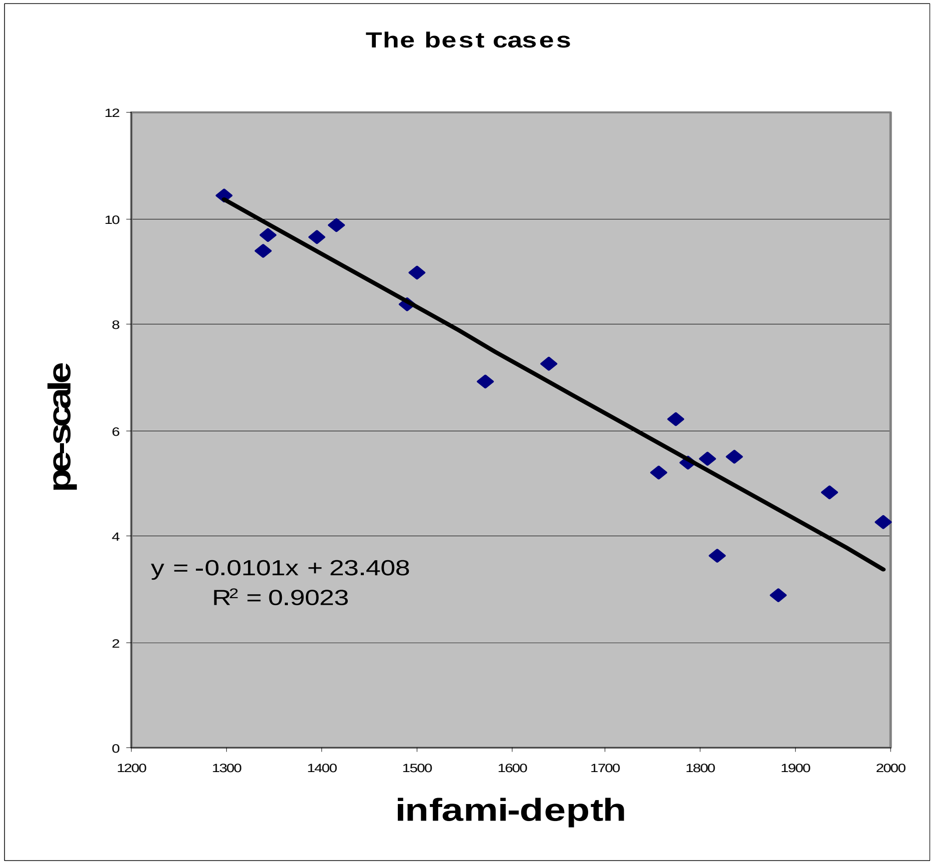


Pe-scale distribution: good cases

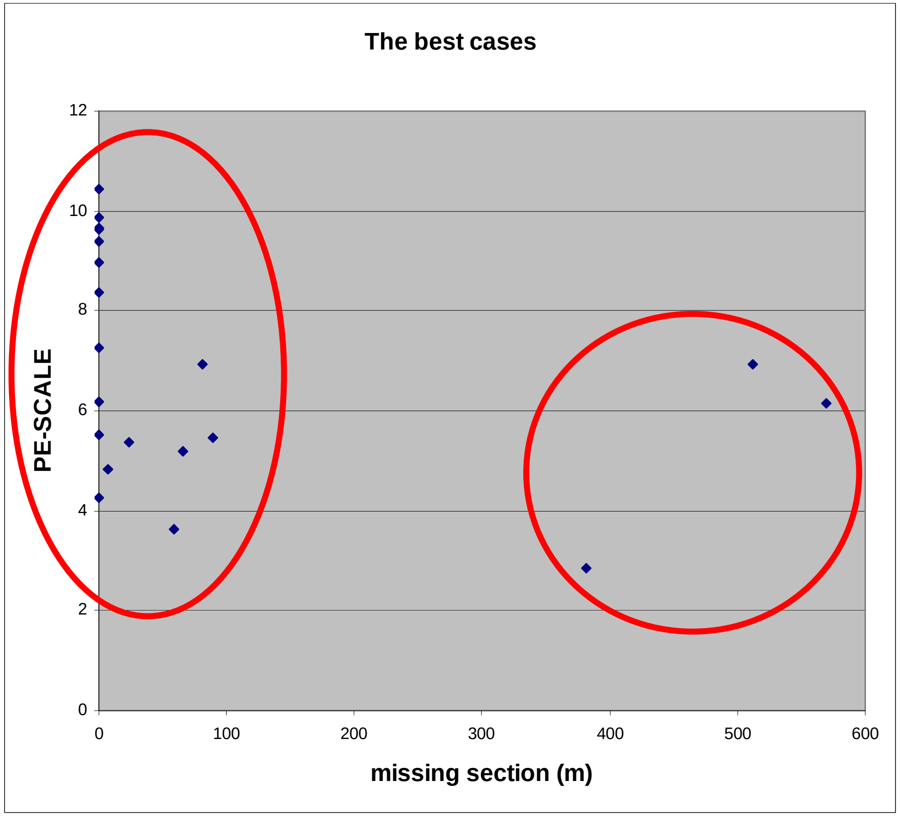


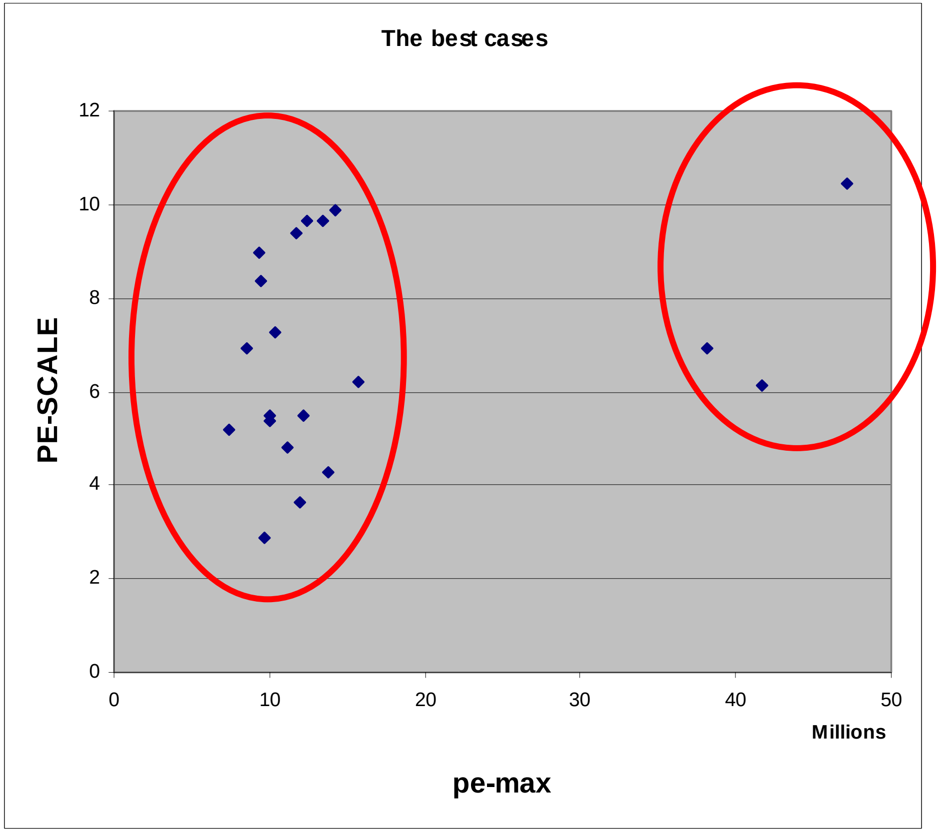
Correlation between variables:



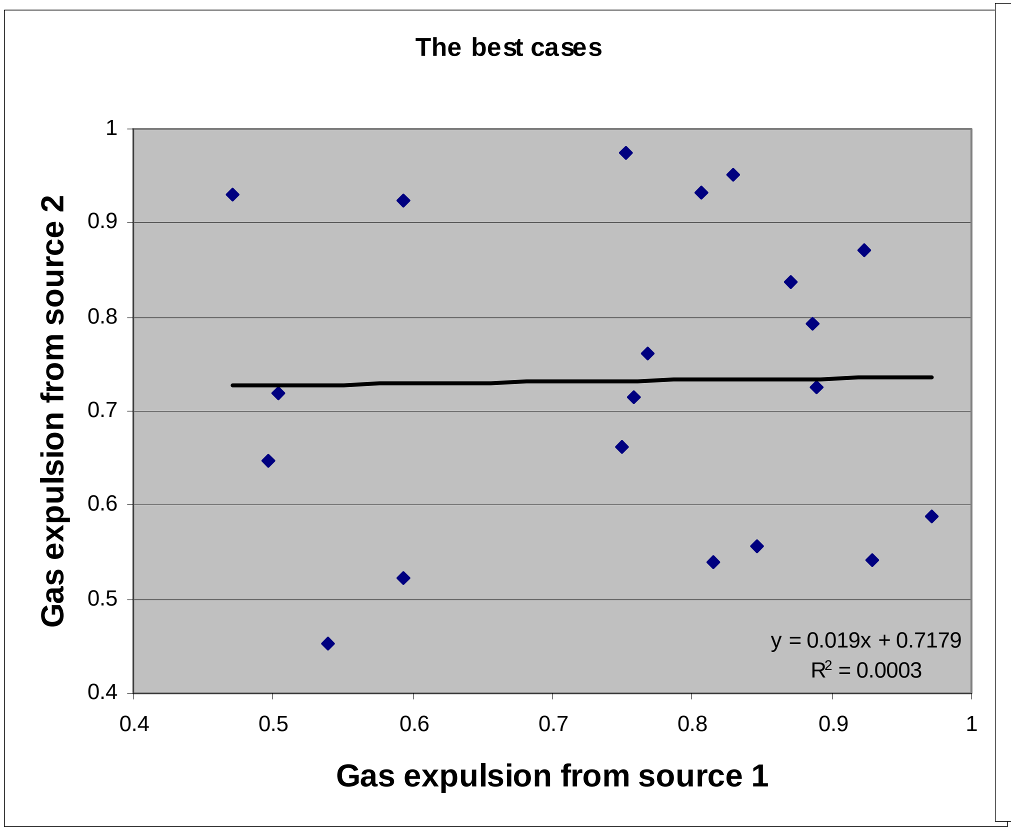


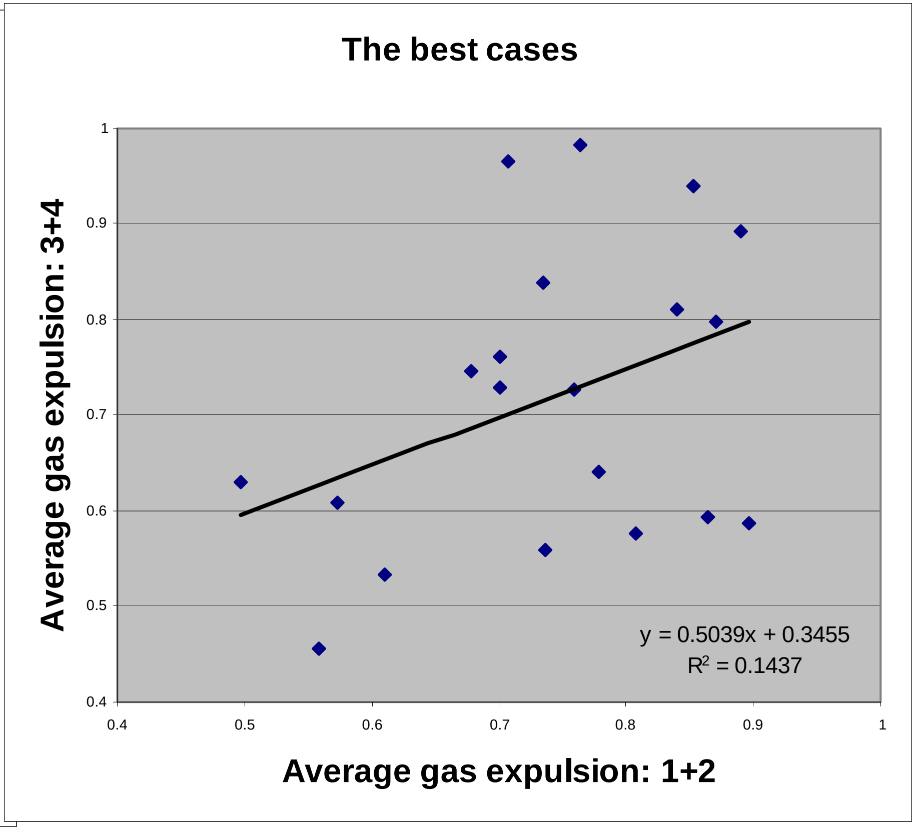
Clustering between variables:



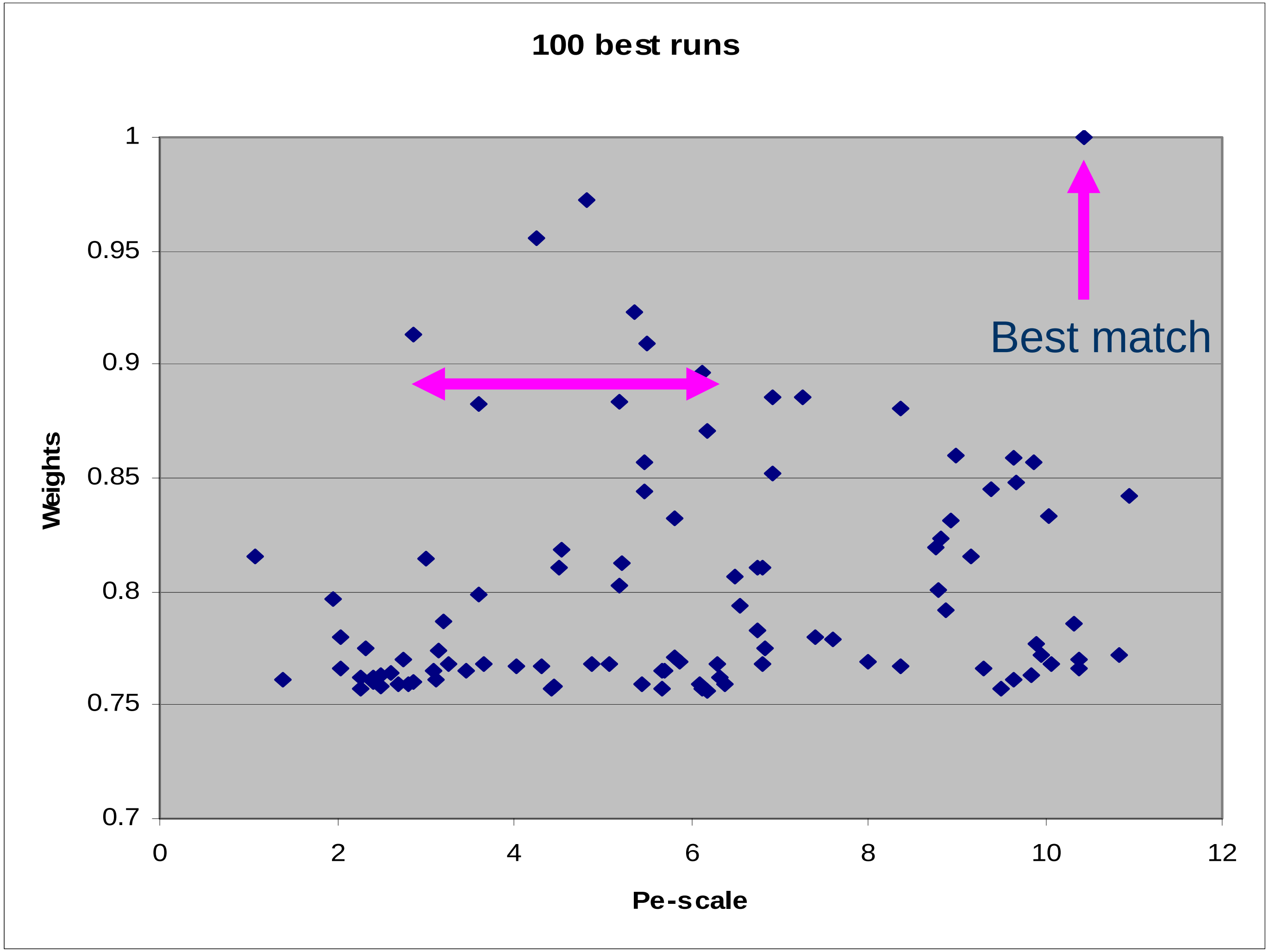


(No) correlation between variables:

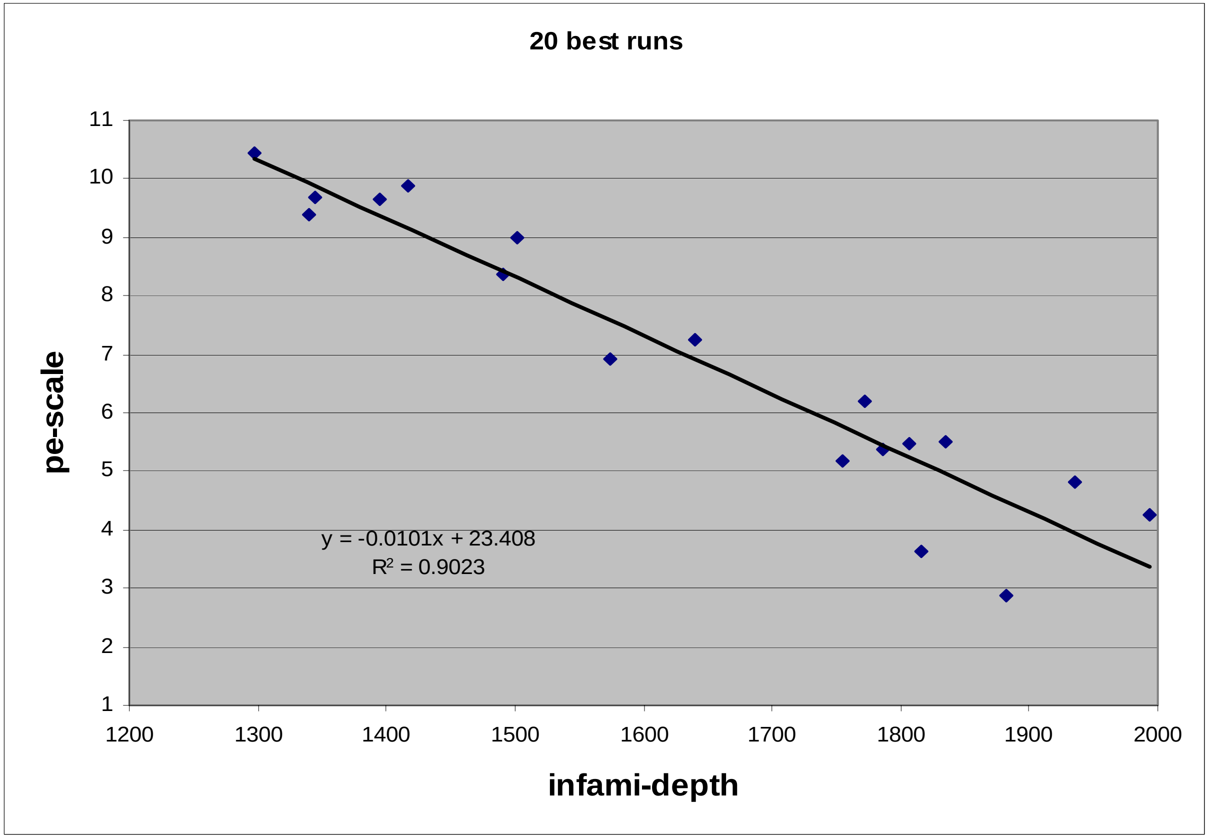




Pe-scale versus normalised weights:



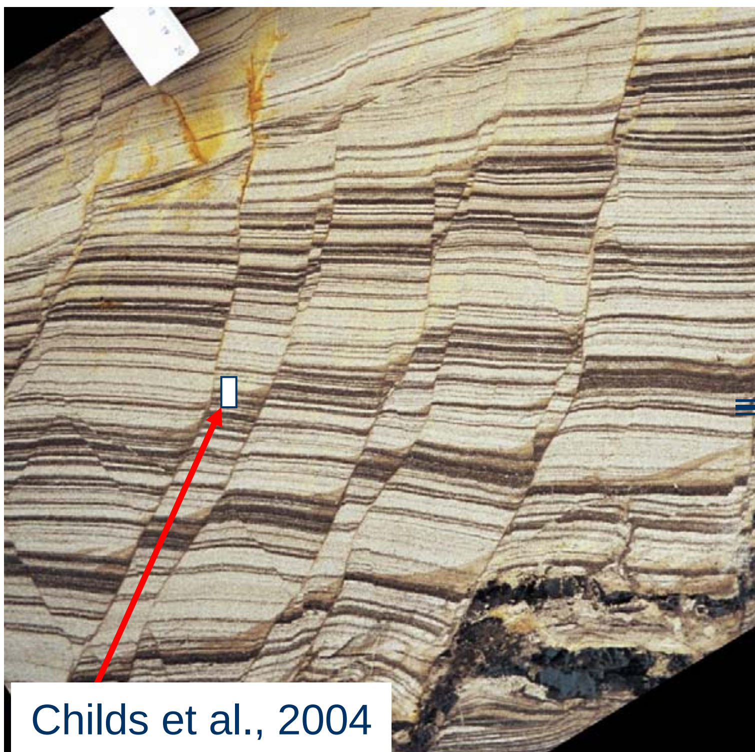
Pe-scale versus infami-depth:



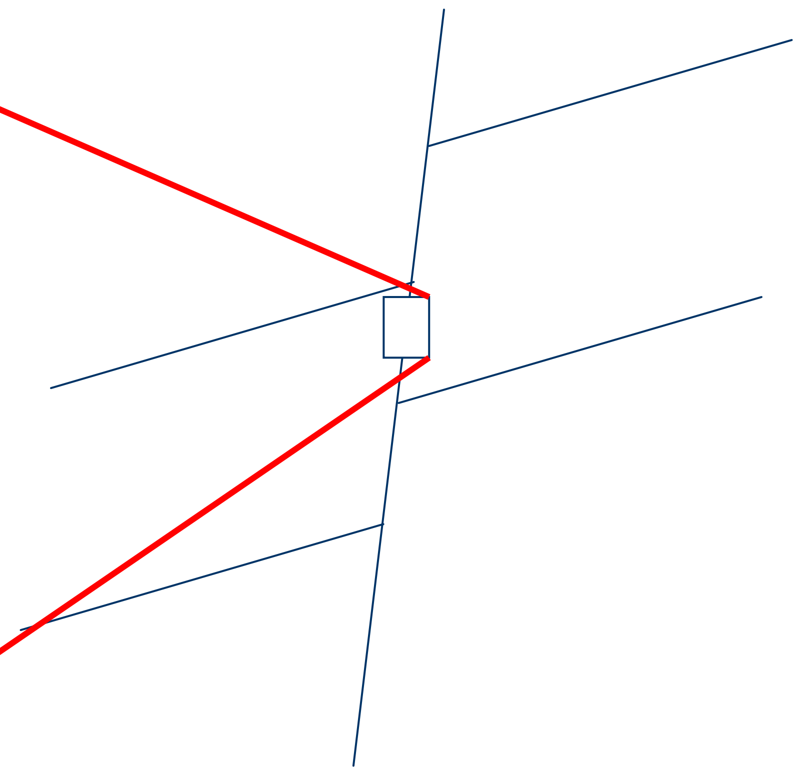
Discussion:
Actual versus Modelled:

The ”real world” (measured)

The ”modelled” world:



Childs et al., 2004



Conclusions

- Pe-scale variable is essential for good fit
  - Pe-scale={2.5-6} & pe-scale=10.43564
- Pe-scale correlates with depth of faulting
  - for low-misfit simulation runs.
- Best simulation runs obtained for
  - infami-missing=0

→ Promising technique, need more cases ←

A Probabilistic Approach to Clay-Smear Fault Seal in Hydrocarbon Migration Modeling for the Tune Field

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- A simulation of hydrocarbon generation and migration into the Jurassic gas-condensate Tune Field south-west of Oseberg has been conducted using a Monte Carlo simulation approach. Tune contains a “proven” fault seal. A model for the entry pressure versus shale-gouge-ratio was implemented in a hydrocarbon migration simulator to account for clay-smear fault sealing. This model accounts for depth of faulting and changes in burial depths through time. The clay-smear model is based upon laboratory measurements of entry pressures and permeabilities from cored faults in well bores.
- A reasonable match to the hydrocarbon migration pattern in the area was achieved through a manual calibration of the hydrocarbon migration model. It was not possible to completely match the drilled oil and gas columns in Tune. Two new parameters were therefore introduced into the model: a “maximum diagenesis depth” and an up-scaling factor from the laboratory data to field scale fault seals.
- A Monte Carlo simulation approach was adapted by specifying important input parameters (not only fault seal parameters) as probability distributions.. A very good match to the Tune wells was provided by the best of the 3000 runs that were completed. The best data fit resulted in an order of magnitude greater entry pressures than modelled by the published formula. There are also quite good simulation runs for scaling factors close to 1, but not for lower values. The study shows that the Monte Carlo approach can be used to bracket fault seal parameter ranges, and thereby reduce uncertainties in fault seal models.

- Faults and Fractures Modeling and Flow I
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