Integration of uncertain subsurface information into multiple reservoir simulation models

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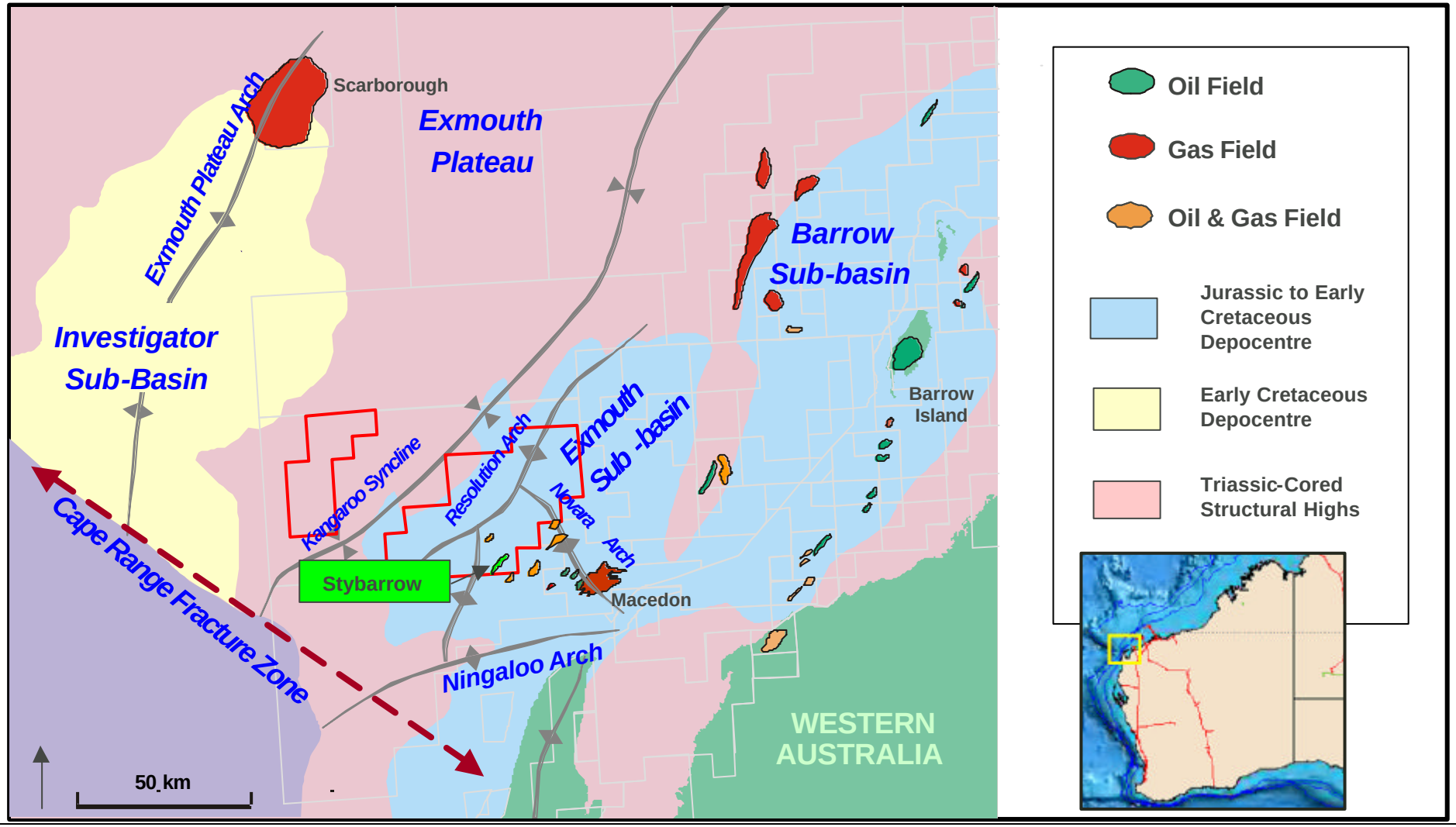
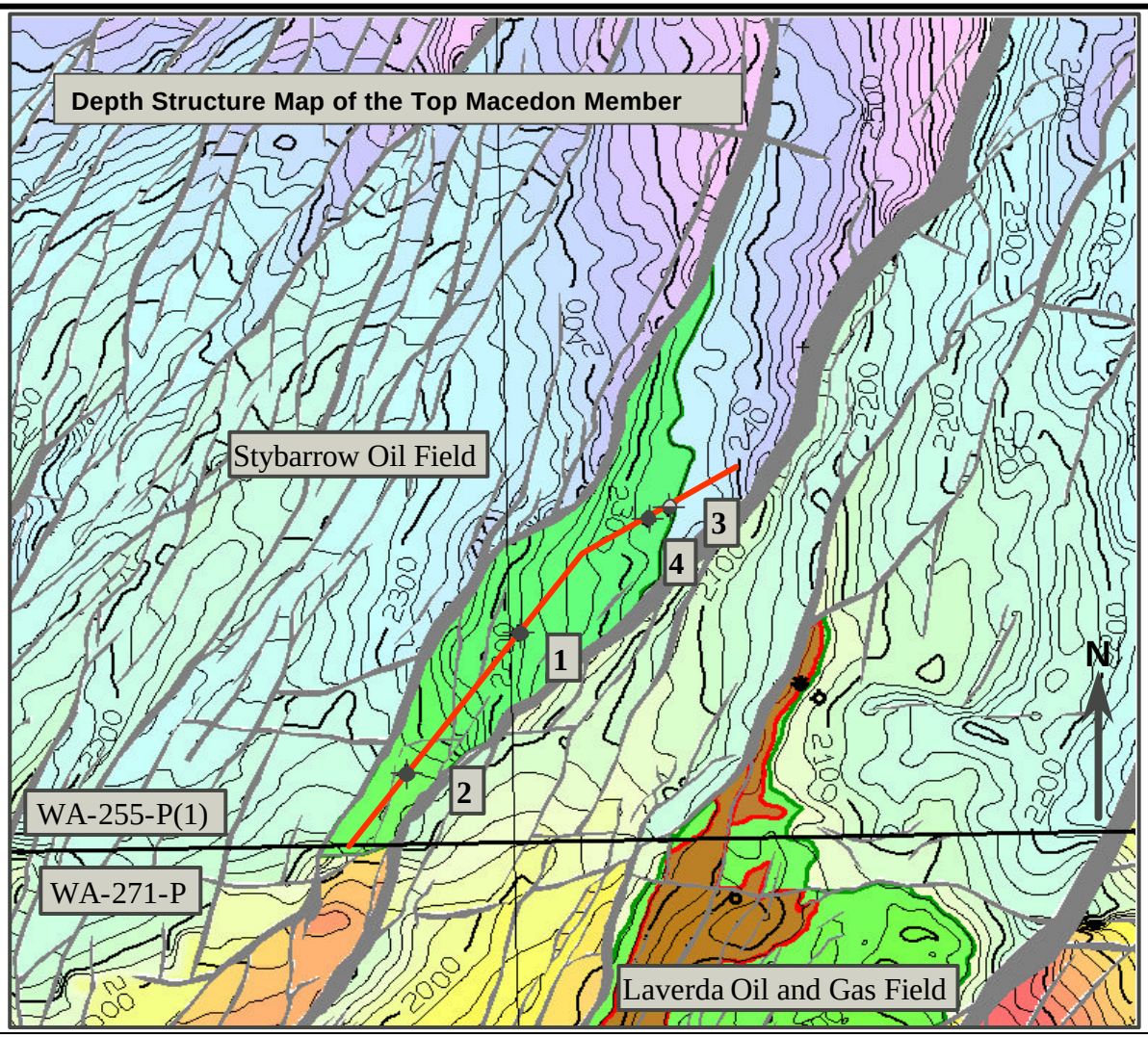
Outline

- Description of Stybarrow oil field
- Use of sparse spike inversion and the correlation wavelet
- Probabilistic wavelet derivation giving critical noise level
- Probabilistic model based inversion with uncertainty
- “Massaging” the results into the reservoir simulation model
- “Decoration” and “Enforcement”
  - adding the subseismic structure

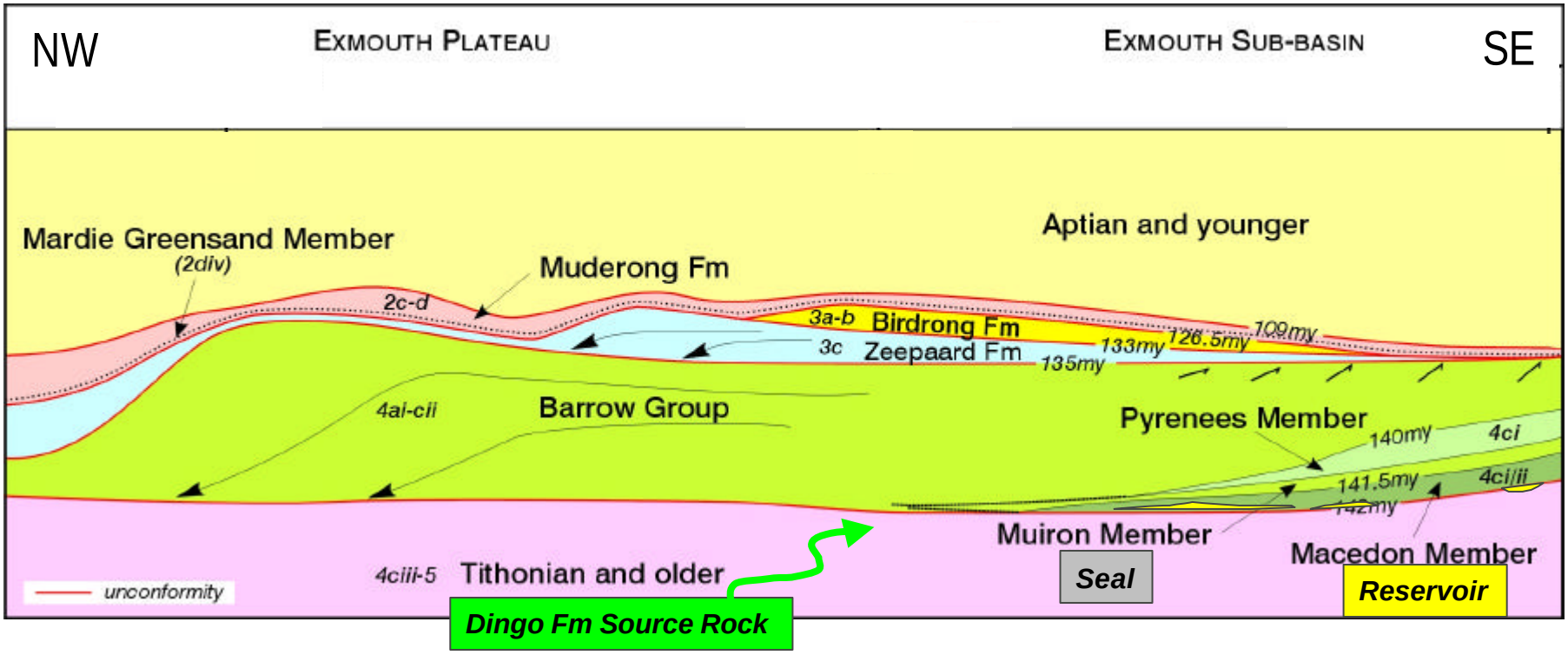
Location of Stybarrow field



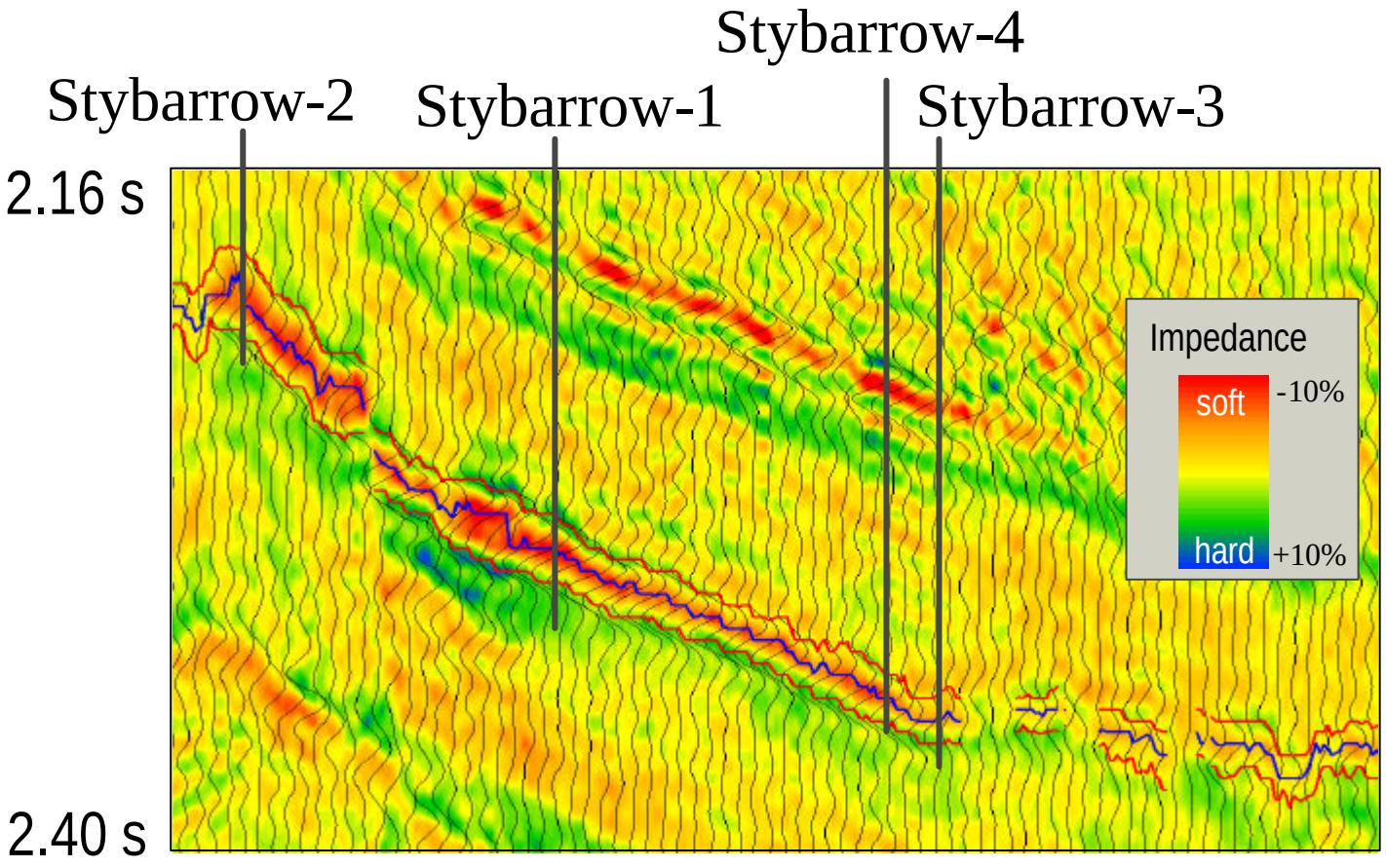
Structure map of Stybarrow field



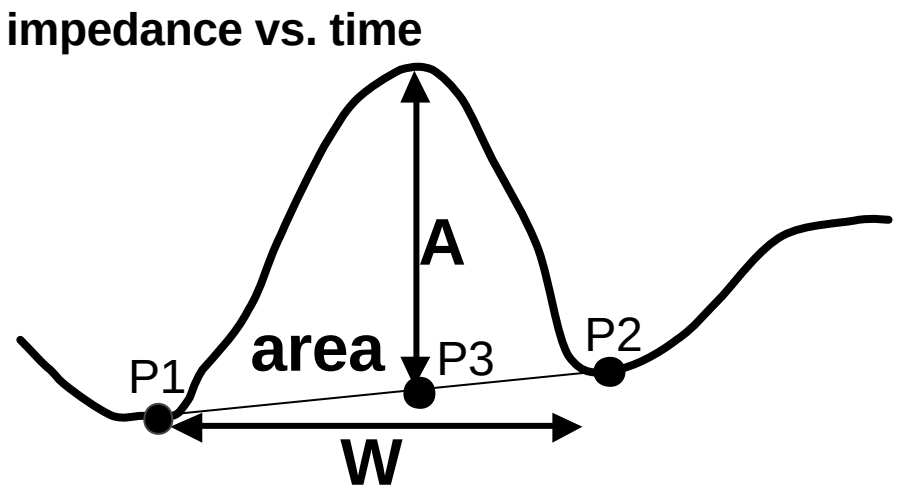
Geologic cross section of Stybarrow



Seismic data and sparse spike inversion with secant amplitude extraction

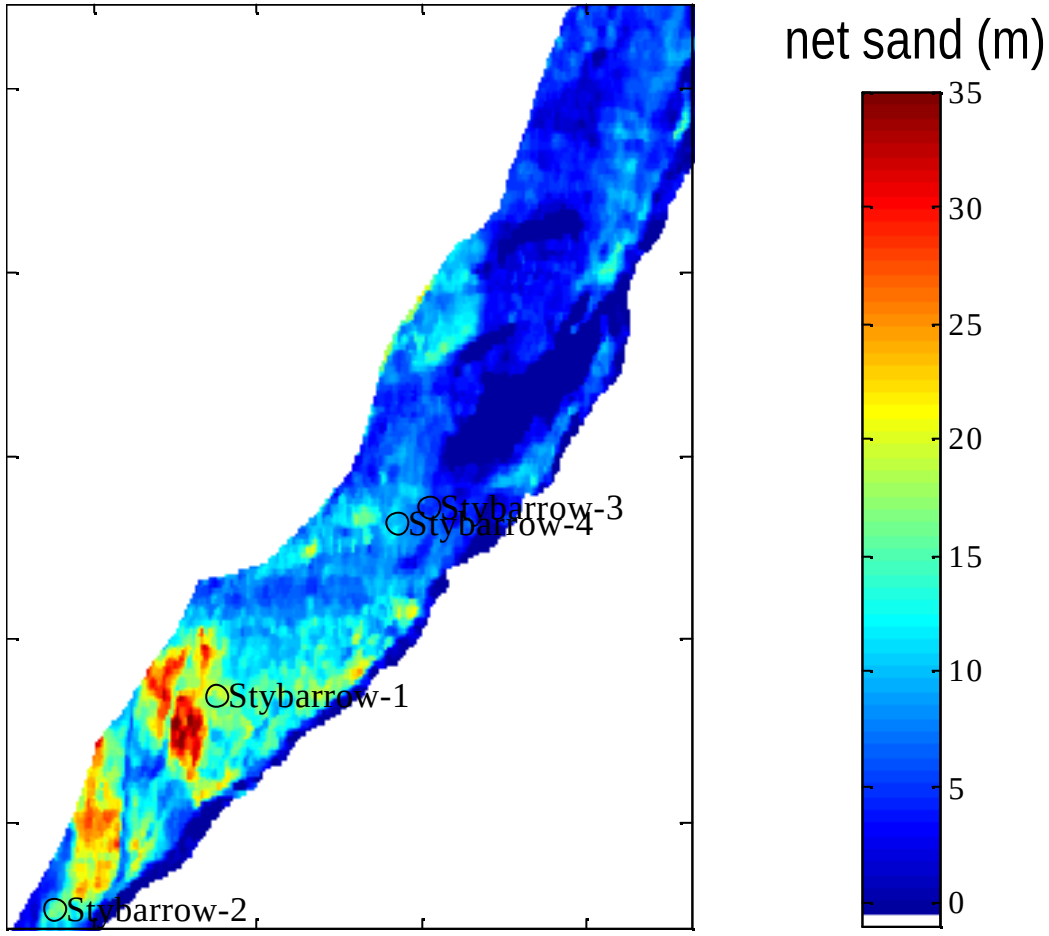


Definition of secant amplitude and area

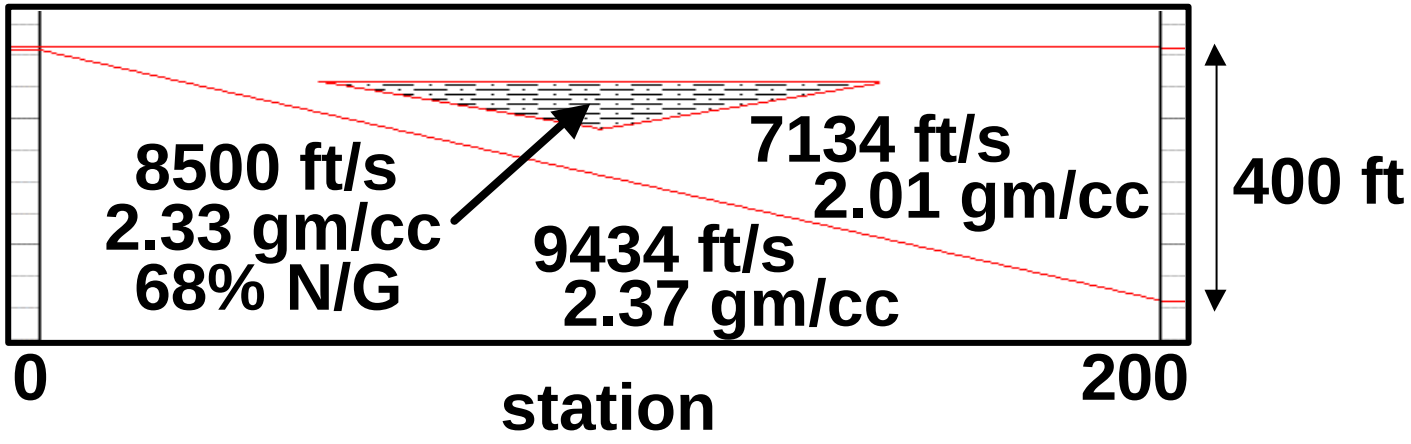


net sand = secant area * Vsand / 2 Rsand

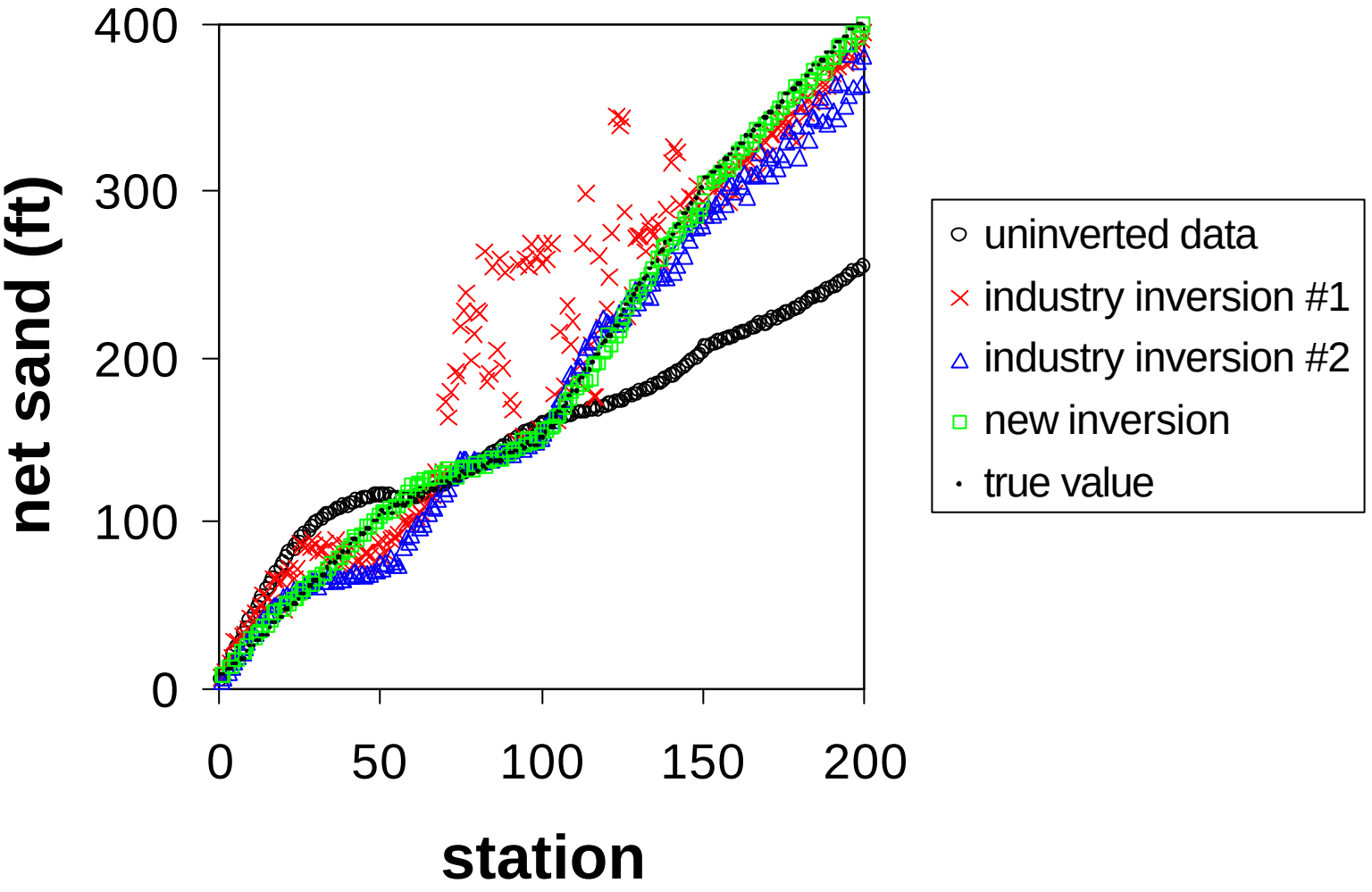
Net sand calculated from secant area



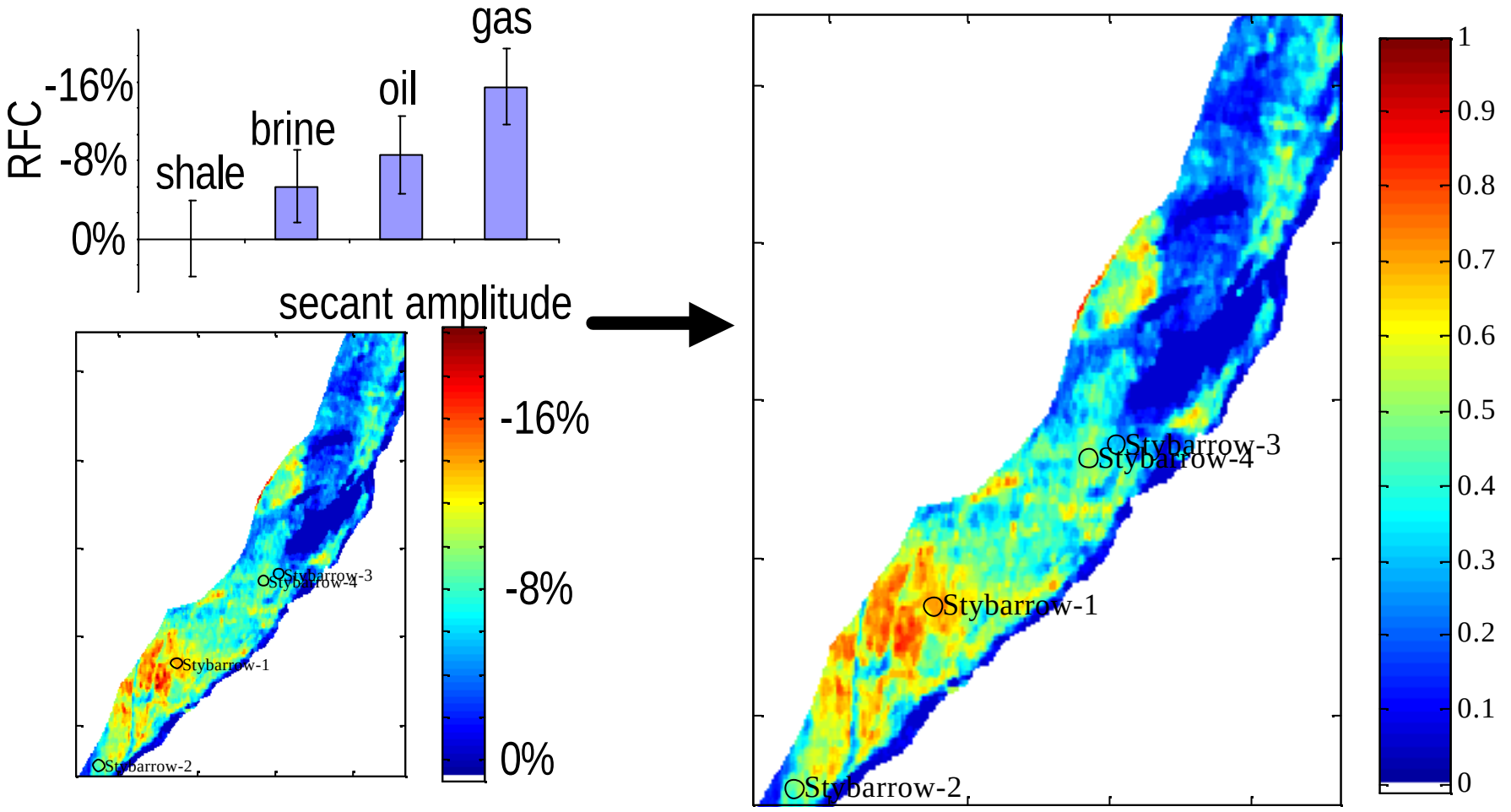
Geometry used for inversion benchmark



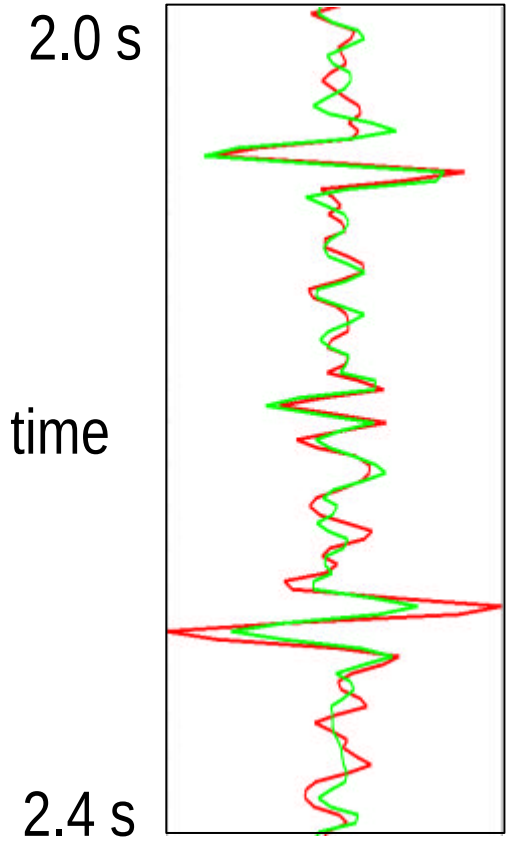
Inversion benchmark



Oil probability map calculated from secant amplitude

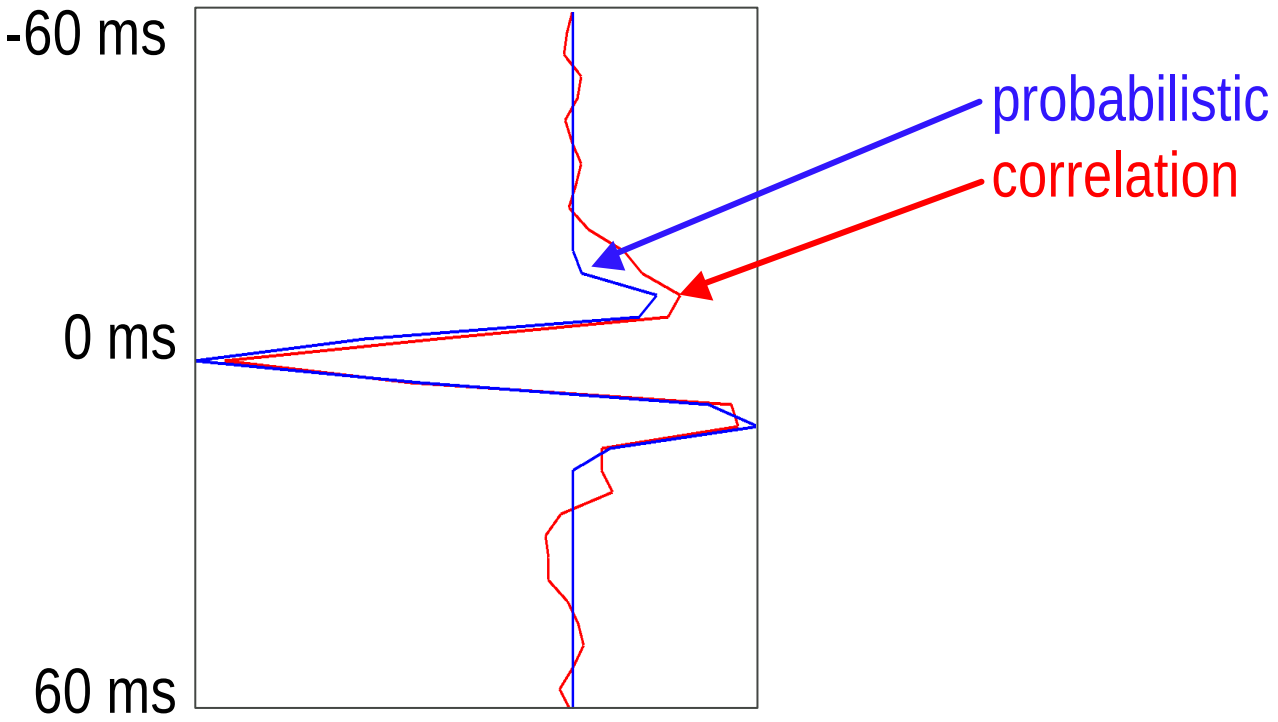


Tie of seismic data to synthetic seismic using probabilistic wavelet derivation



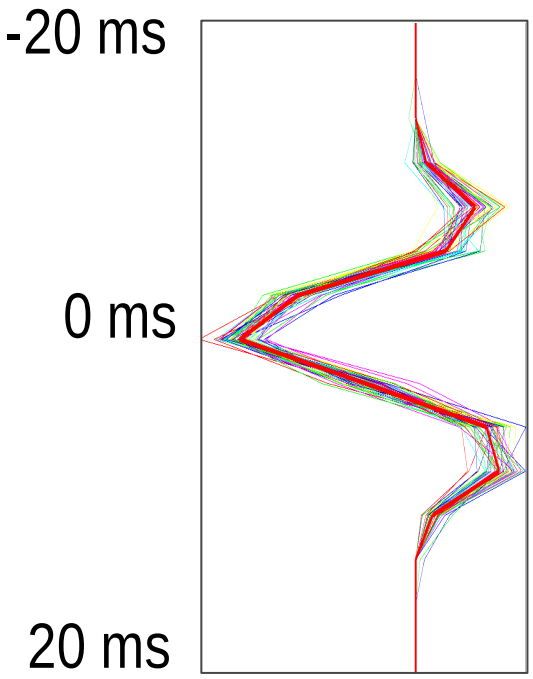
green = seismic
red = synthetic

Most likely probabilistic wavelet compared to correlation wavelet



note: probabilistic wavelet is much shorter than correlation wavelet

Most likely probabilistic wavelet compared to ensemble of possible wavelets

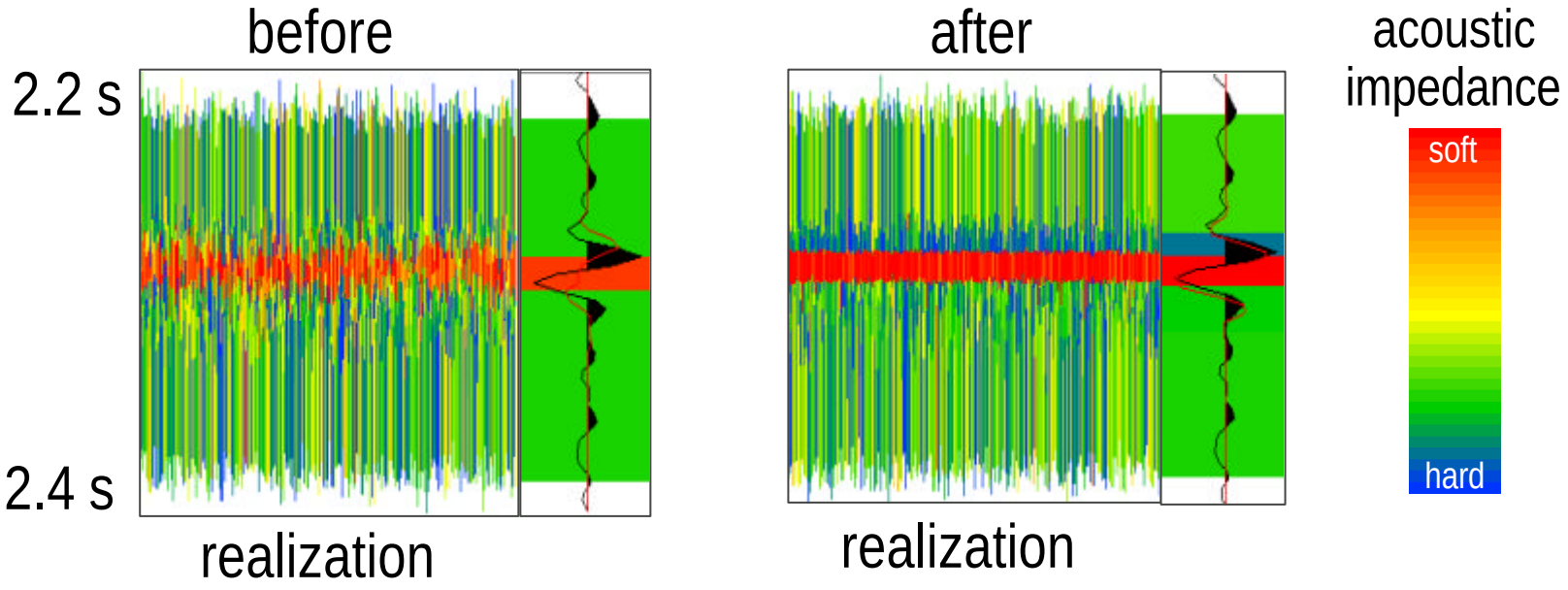


note: noise is 17% size of oil reflector, SNR is 15 dB

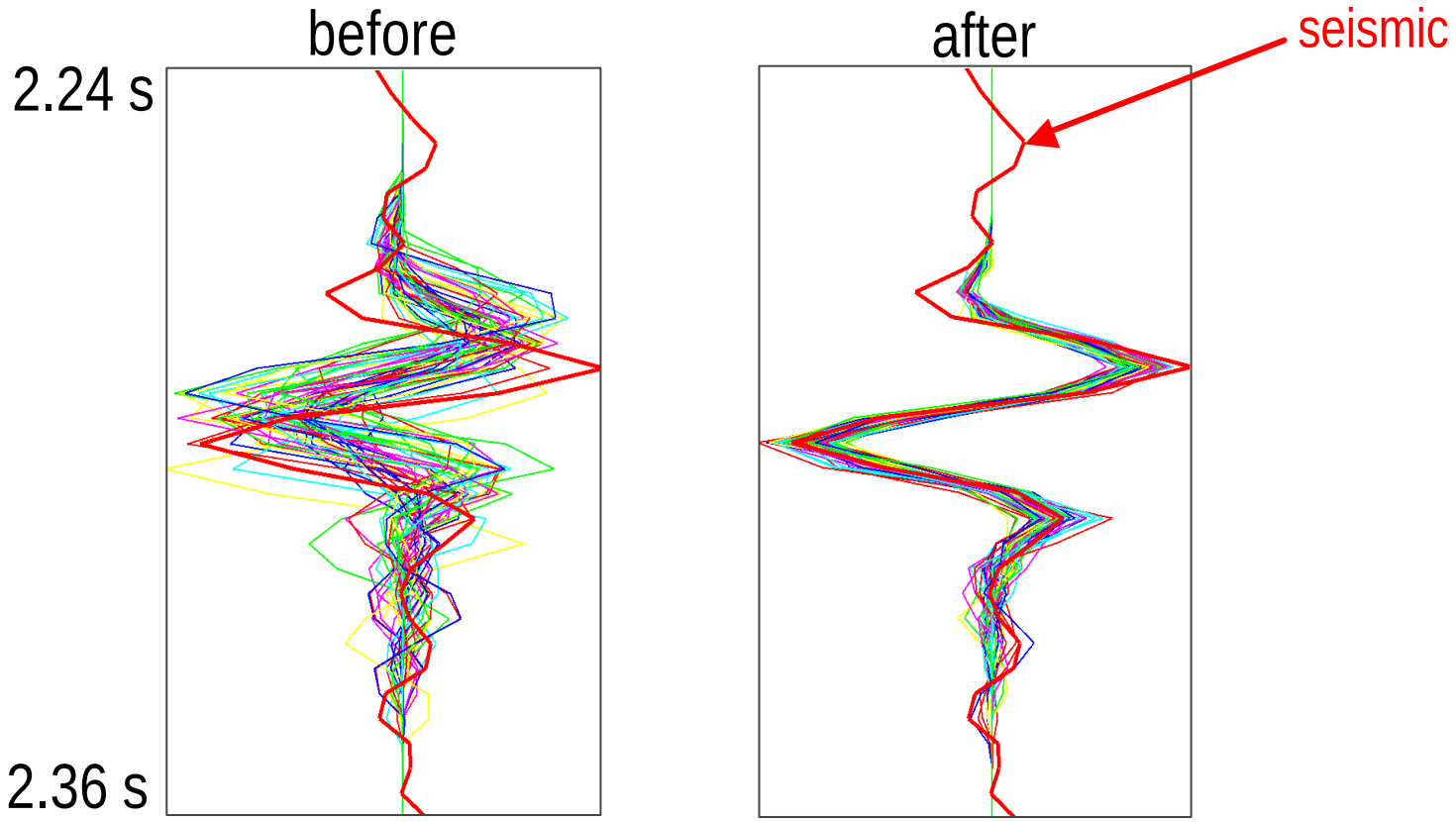
Probabilistic model based inversion

- Layer based model built at seismic loop scale using sparse spike inversion
- Standard rock physics correlations estimated with uncertainty
- Fundamental properties of layers are:
  - net-to-gross ratio (N/G)
  - layer top and base
  - fluid type
- Ensemble of models generated that are consistent with seismic to within estimated noise level

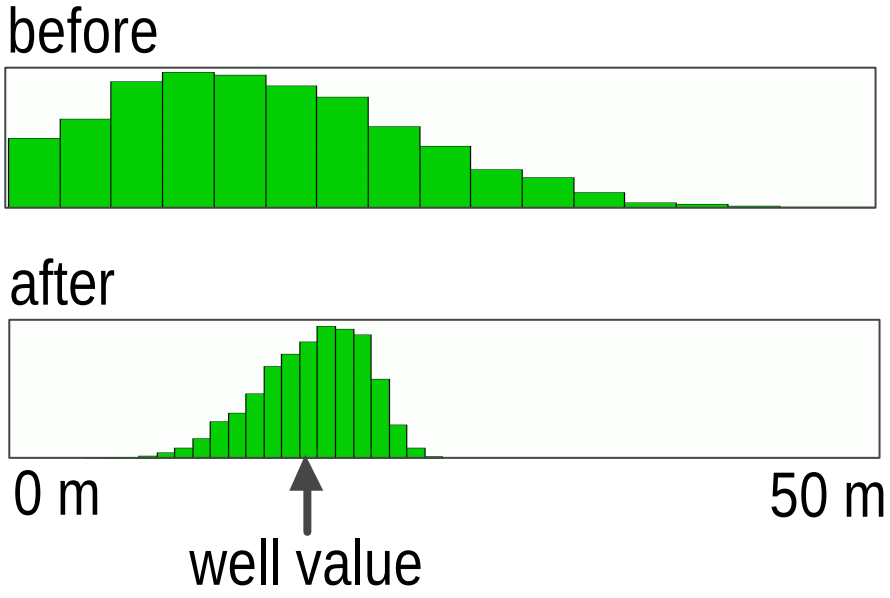
Ensemble of models at Stybarrow-1 well location show effect of model based inversion



Effect of model based inversion on match of synthetic seismic to seismic data

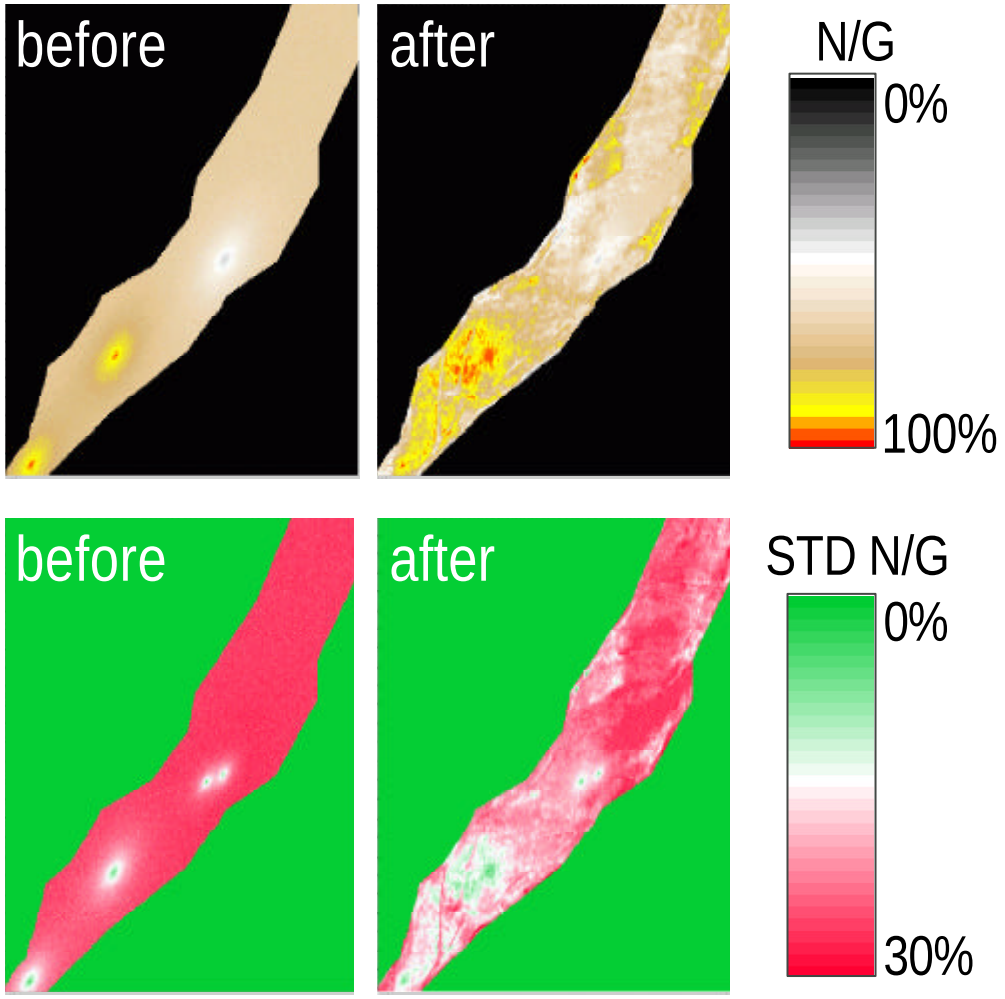


Inversion tightens the range of possible net sand

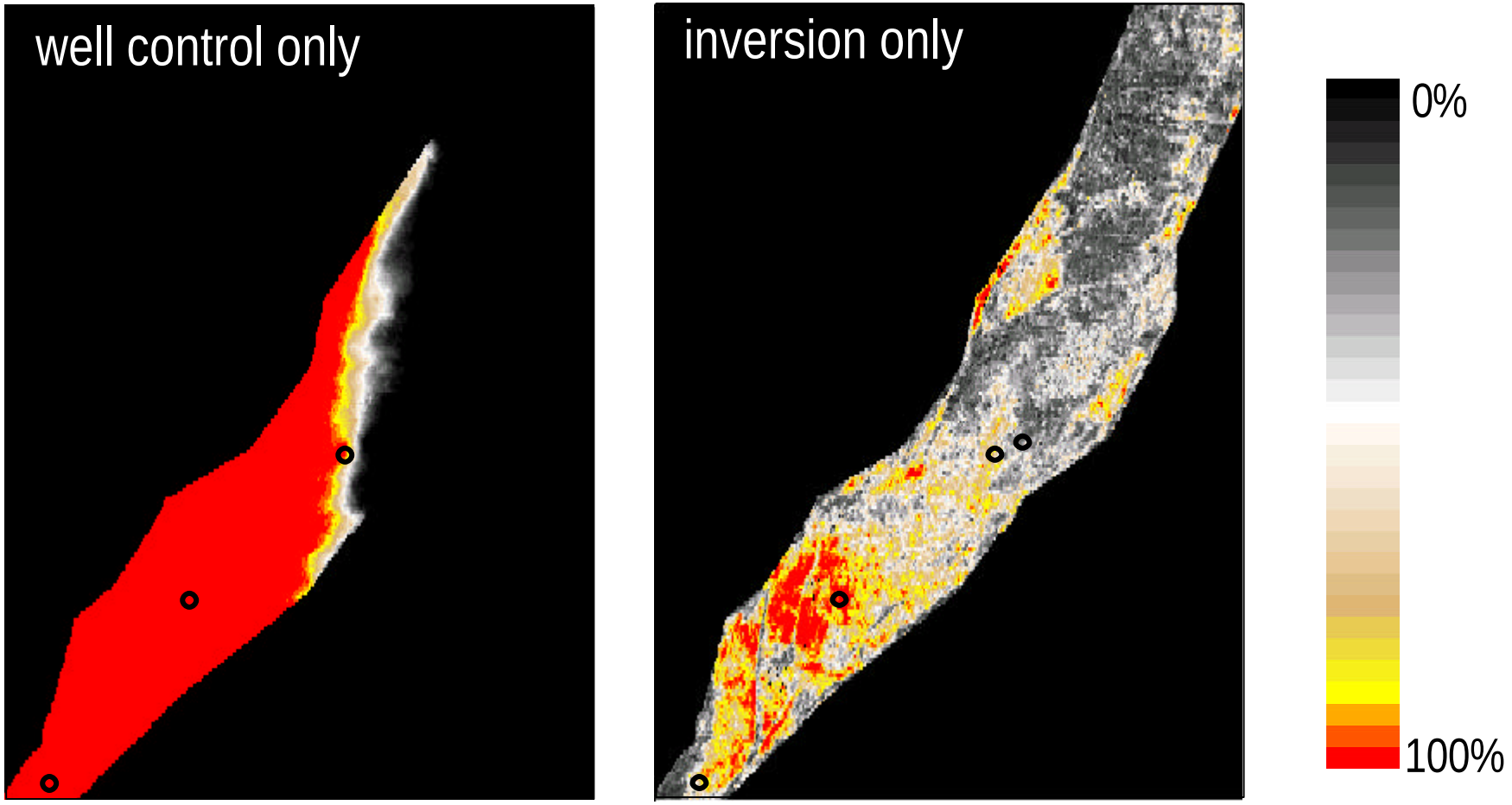


probability of oil increased to 97% from 50% (oil in sand at this location)

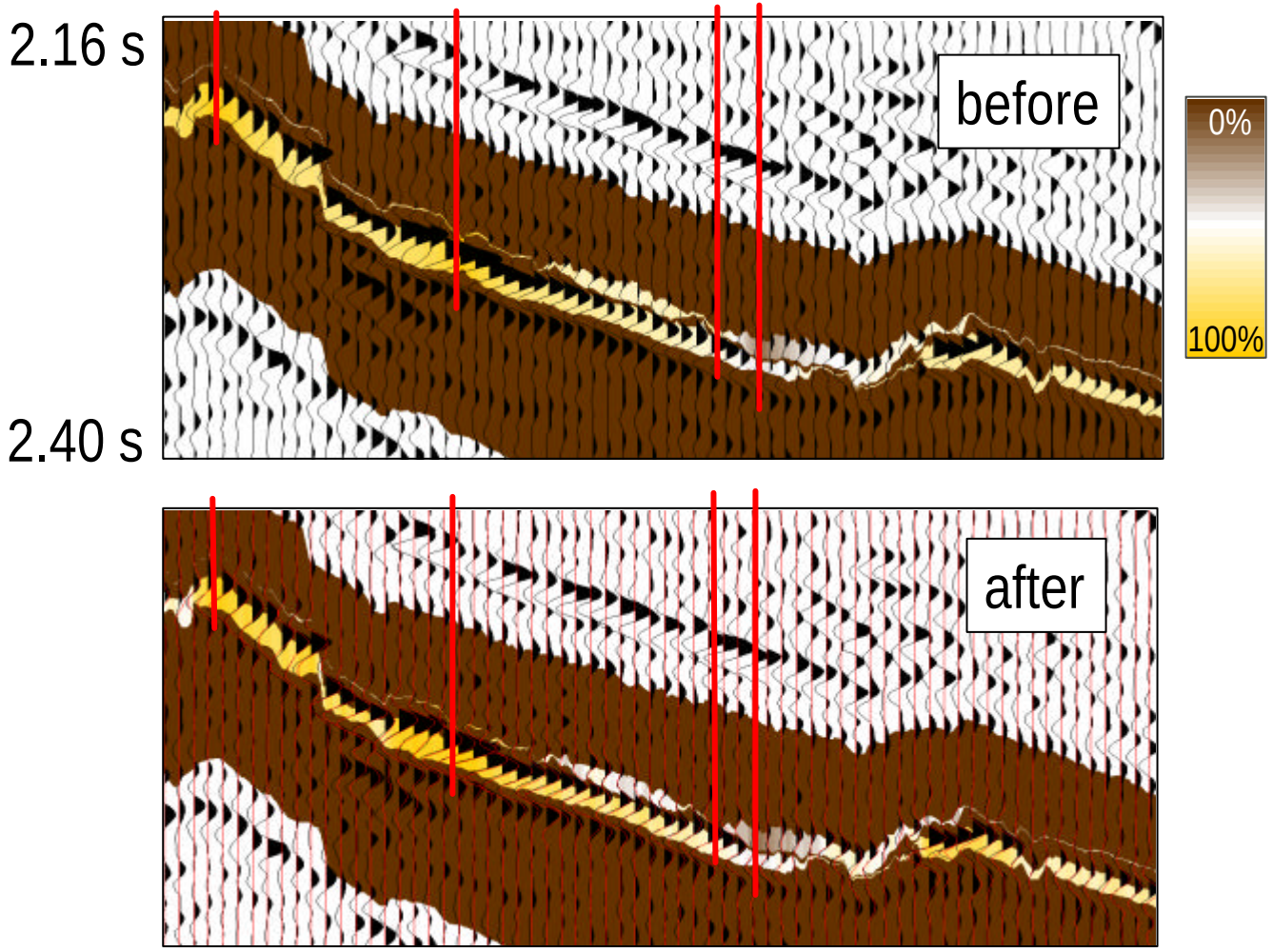
Effect of inversion on estimation of N/G in main hydrocarbon (krieged to wells)



Estimation of oil probability



Cross sections of mean model



Net sand prediction ahead of drill bit

well	prediction (m)	result (m)
Stybarrow-3	9.1 ± 6.4	2
Stybarrow -4	12.3 ± 4.3	7.6

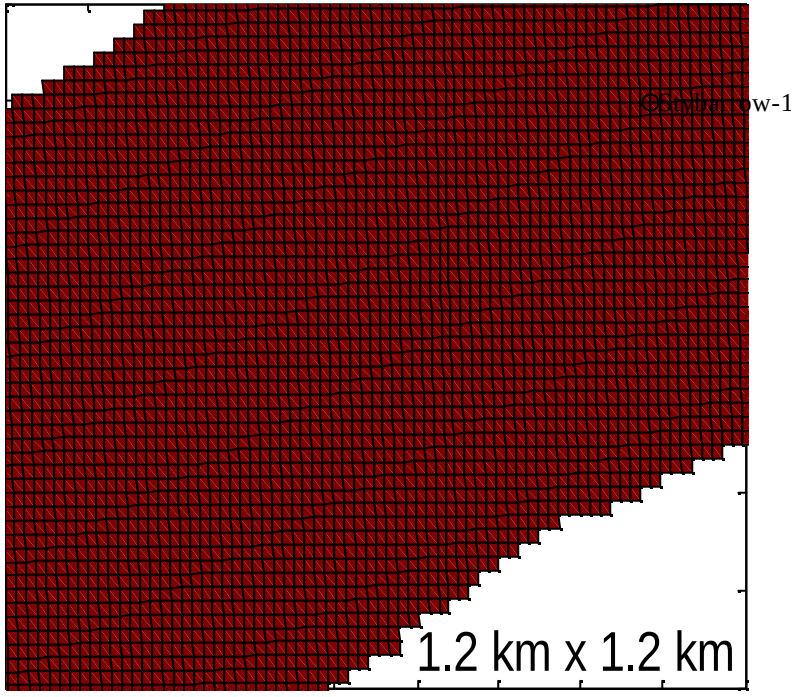
40% probability well values larger deviation than observed

Results of model based inversion "massaged" onto reservoir model

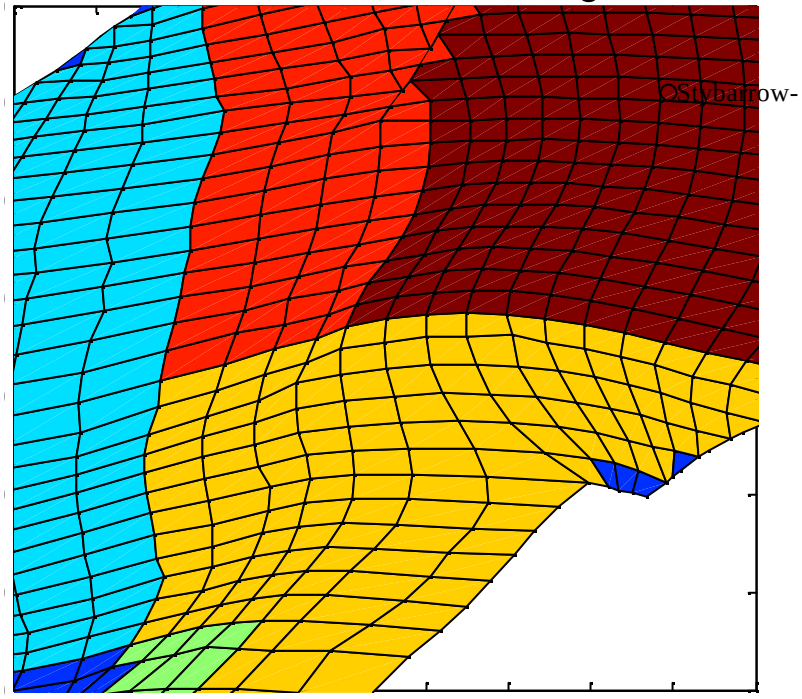
- Lateral correlation added
- Short range noise eliminated
- Put onto irregular corner point geometry
- Fault blocks honored
- Inter-layer and inter-property correlation honored

Difference between the seismic grid and the reservoir simulation grid

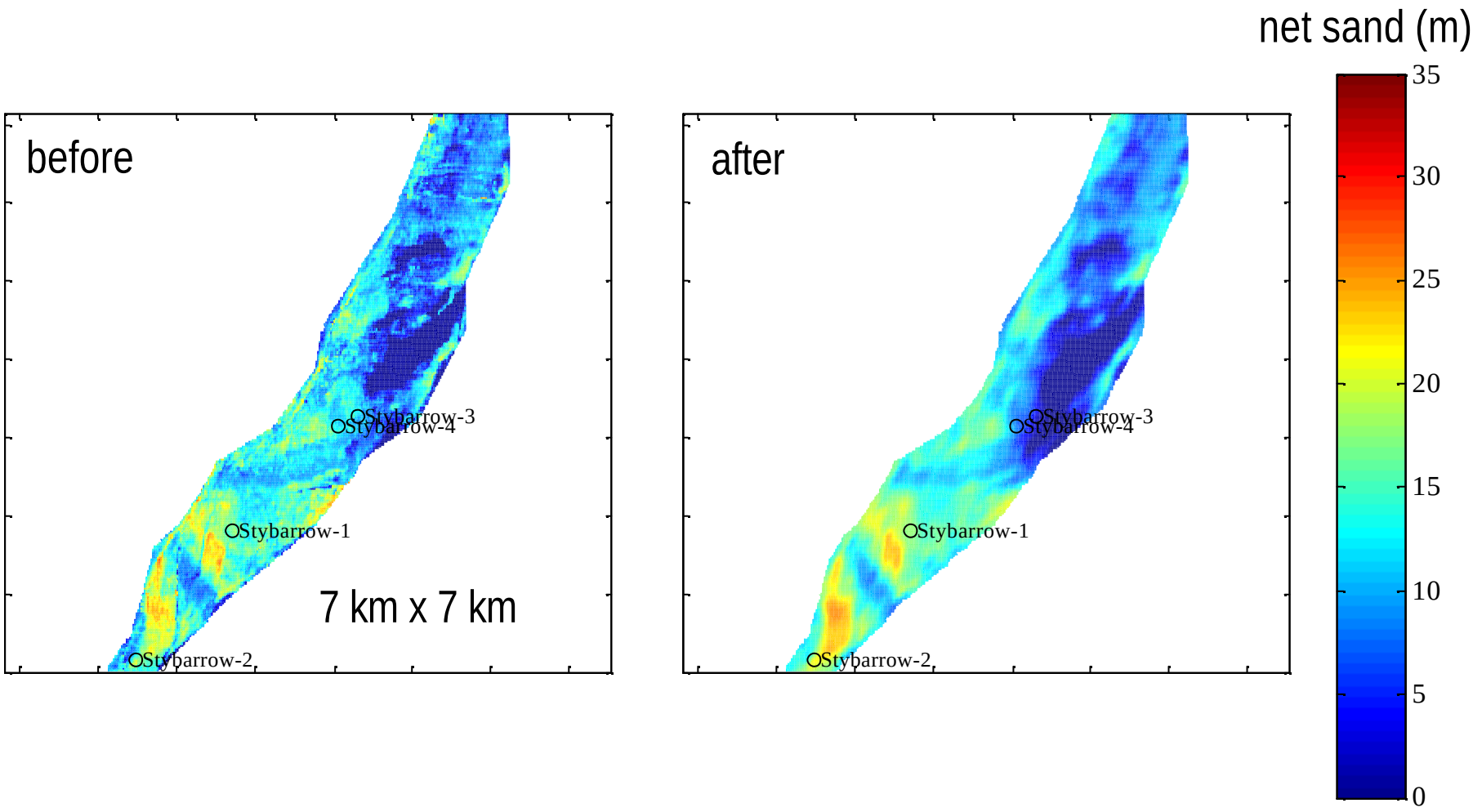
seismic grid



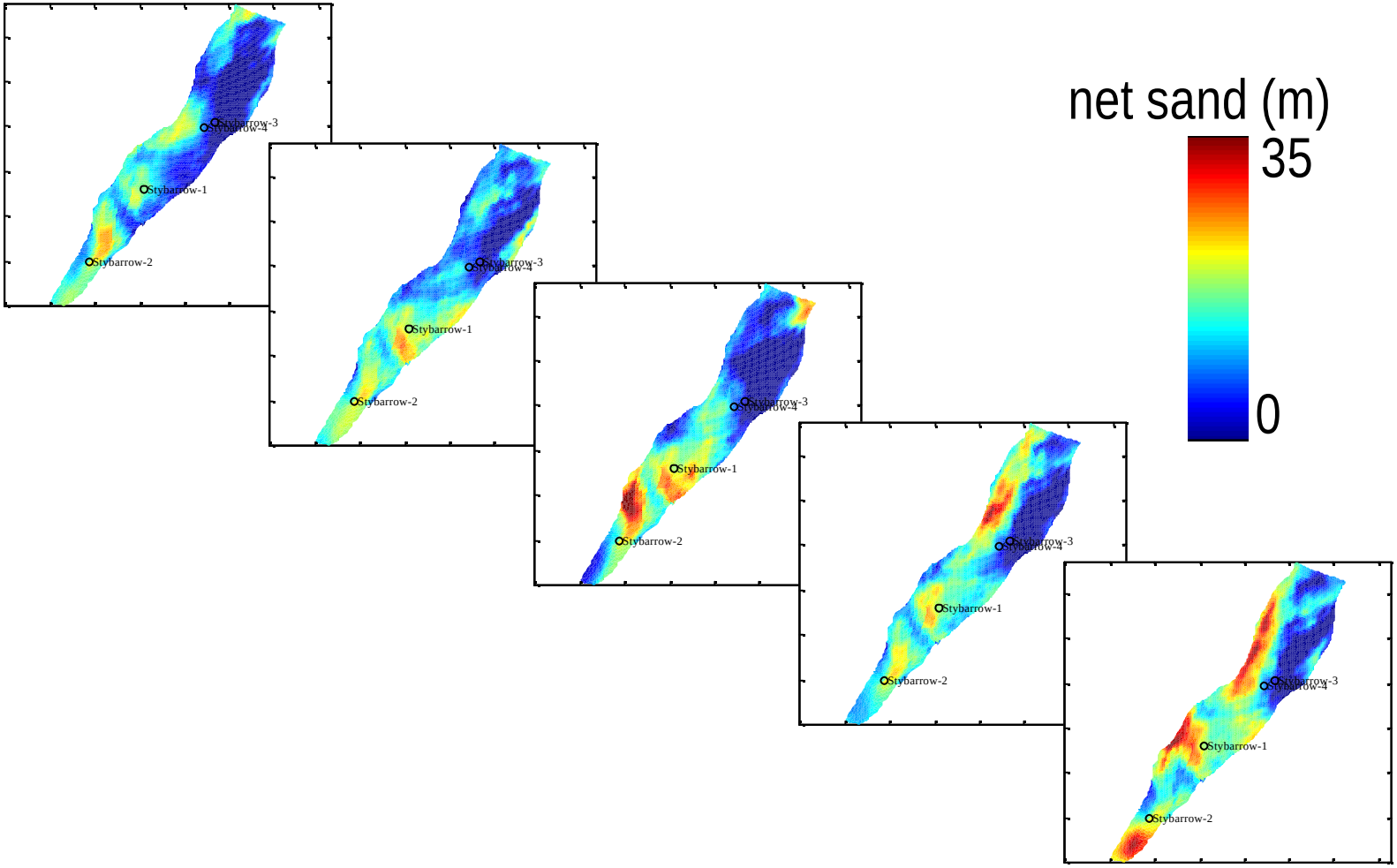
reservoir simulation grid



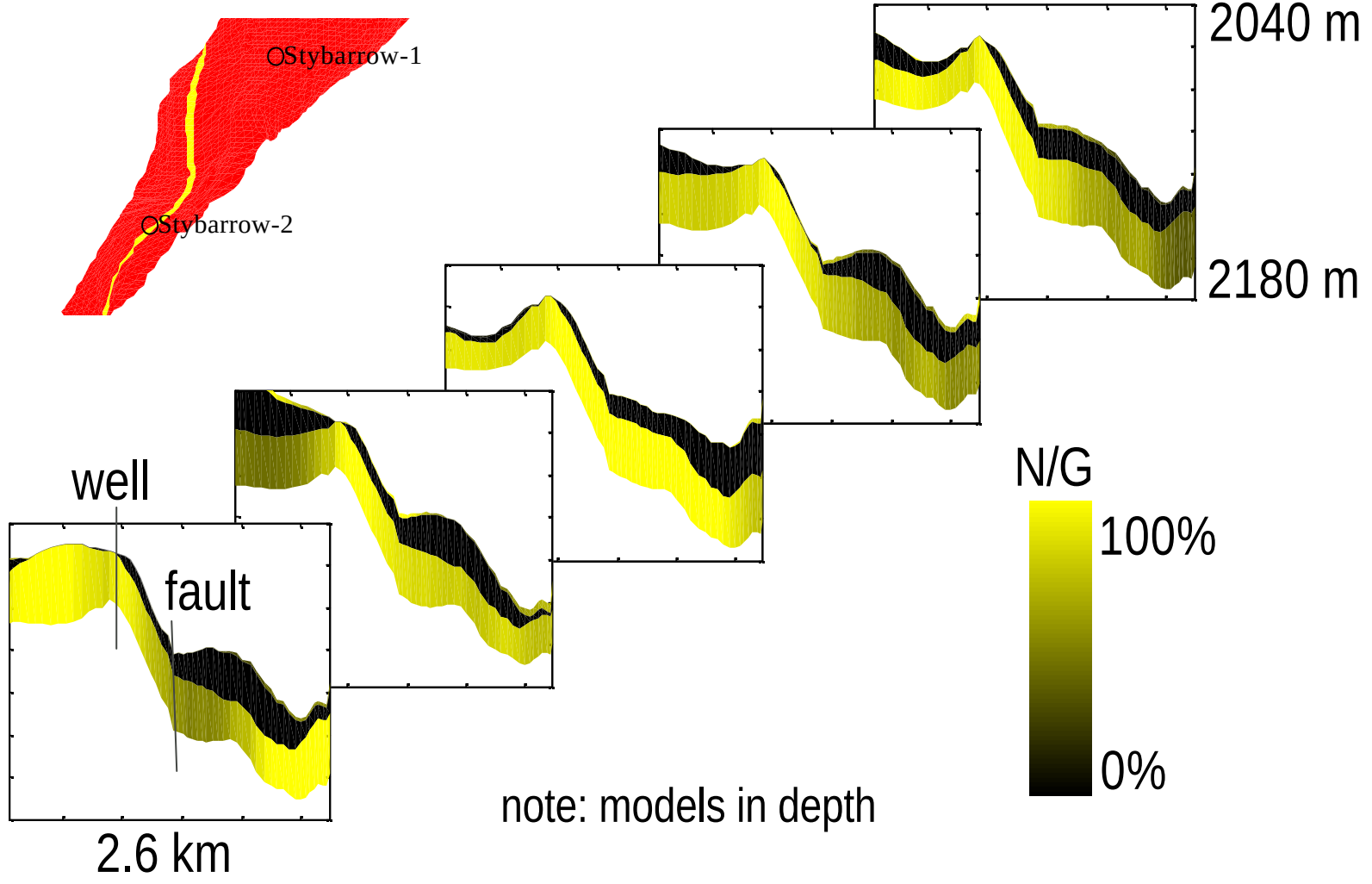
Effect of massaging on mean net sand map



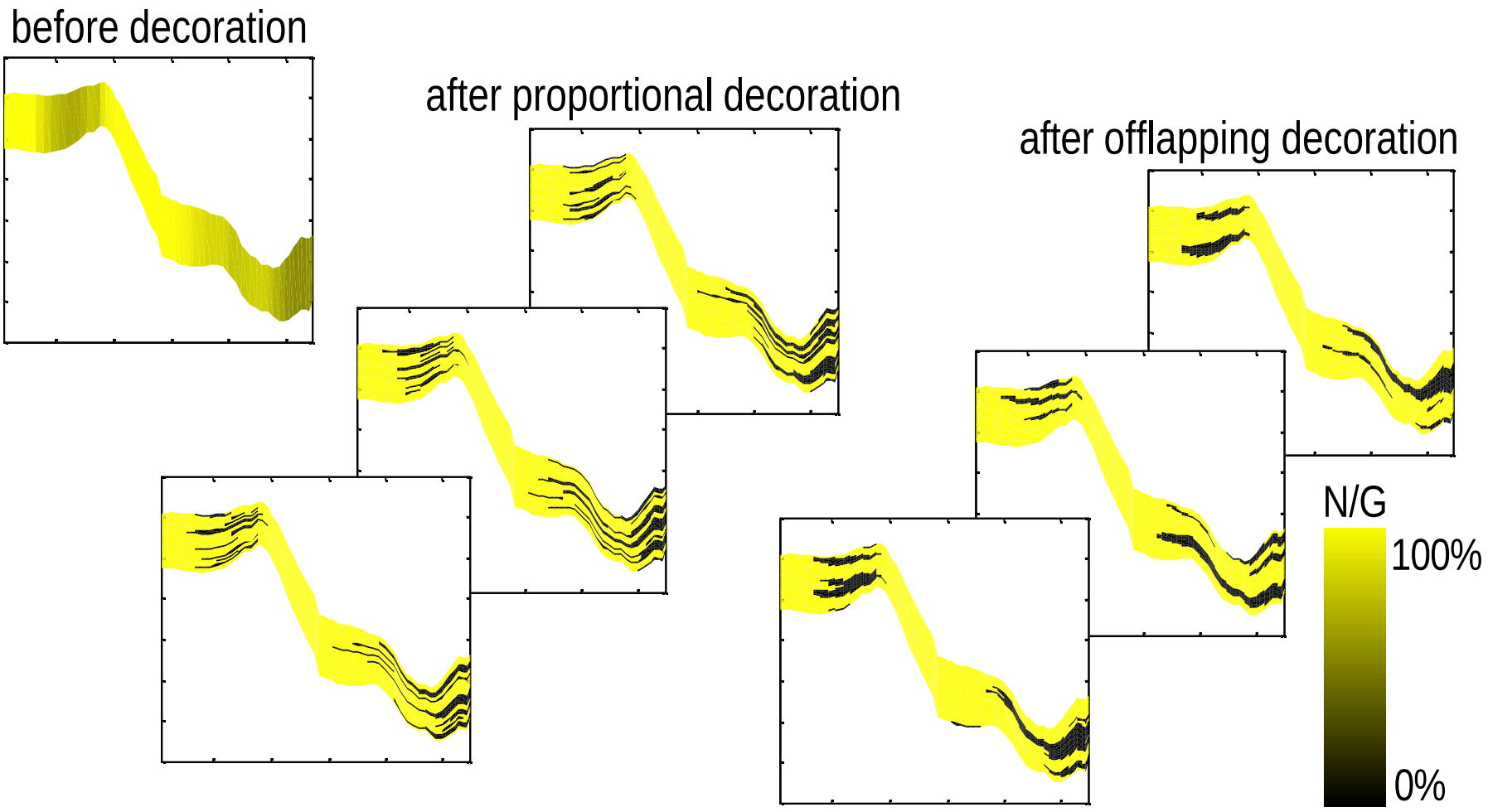
Realizations of net sand generated by massager



Cross sections through model realizations



Reservoir simulation models are “decorated with subseismic structure



Conclusions

- Ensemble of reservoir simulation models consistent with:
  - Seismic data
  - Well information
  - Geologic concepts
- Gives:
  - Volumetric distributions
  - Minimum net sand (well completion)
  - Etc.
- Range of production profiles
  - Potential production
  - Risks for development