



# Integrating Stochastic Rock Physics in Seismic Pre-drill Prospect Risk and Reservoir Quality Assessment

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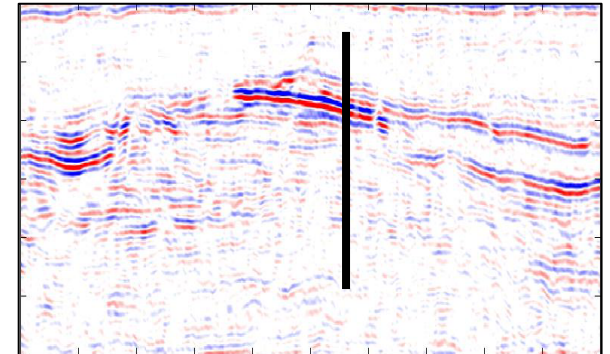
**StatoilHydro**





# Our goal

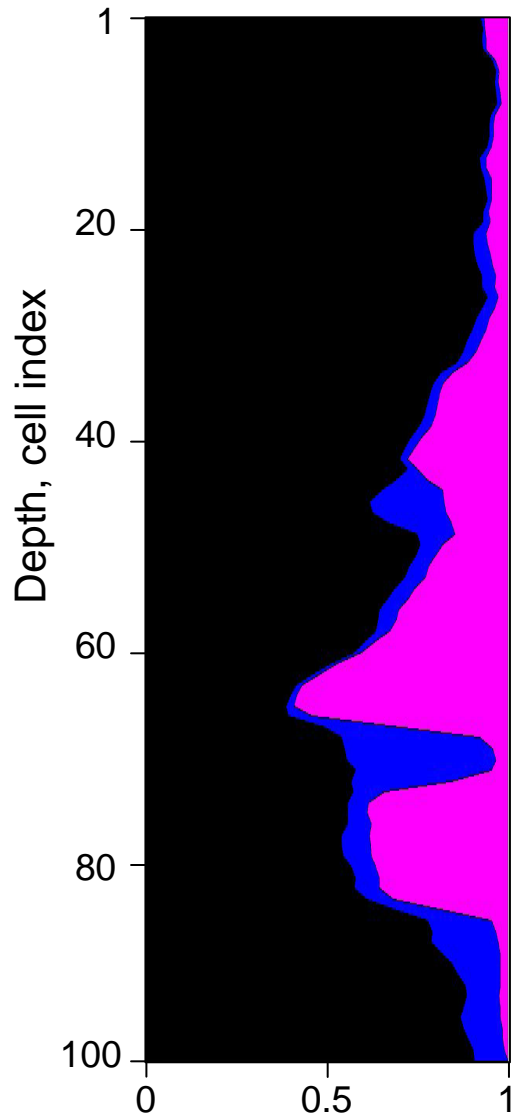
- Method for pre-drill assessment of potential well locations
  - probability of discovery
  - hydrocarbon volumes with uncertainty
- Using seismic amplitude data
- Studying 1D vertical profile





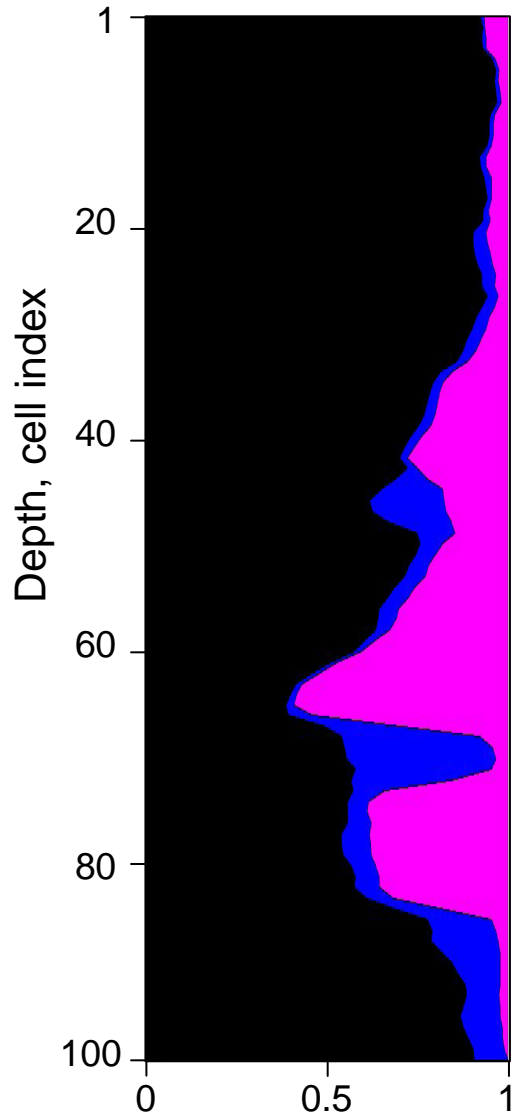
# Predicting HC volumes

Point-wise probabilities

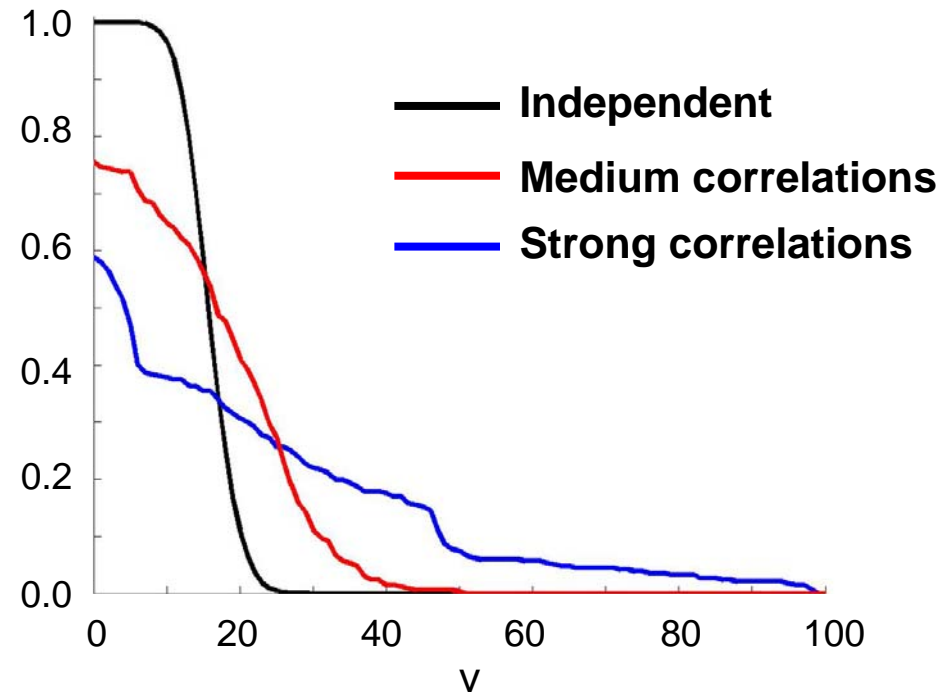


# Predicting HC volumes

Point-wise probabilities



$P(\text{HC volume } V > v)$



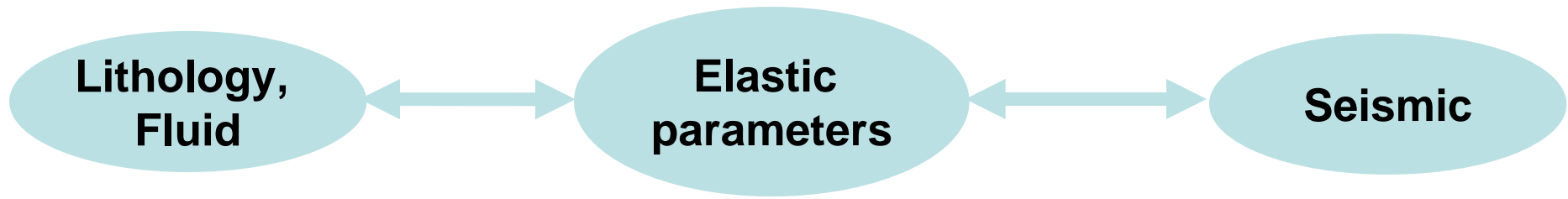
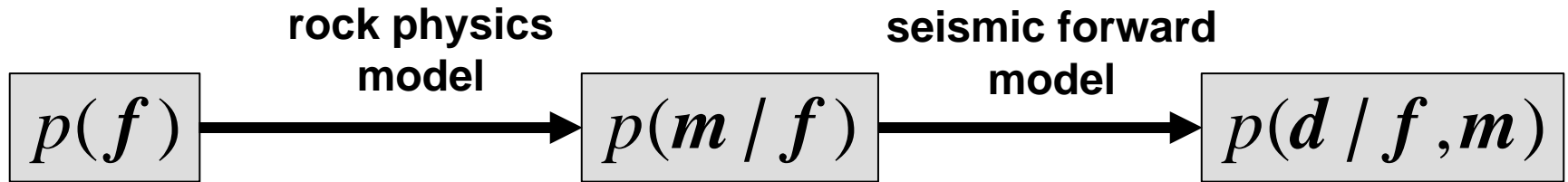
Different vertical correlation structures

- $E(V)$  identical
- $P(V > 0)$  different

Which curve to trust? Need sound modeling!

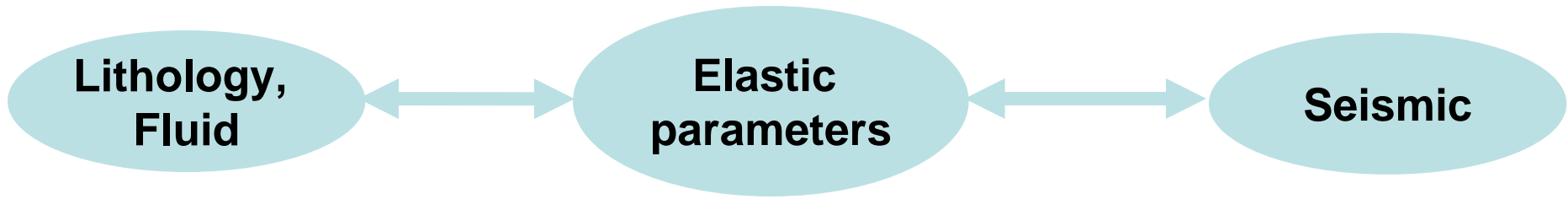
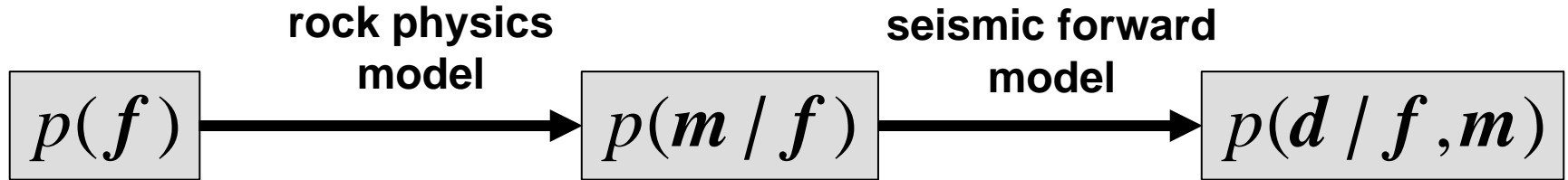


# Model overview





# Model overview



$$p(f, m | d) \propto p(d | f, m) p(m | f) p(f)$$

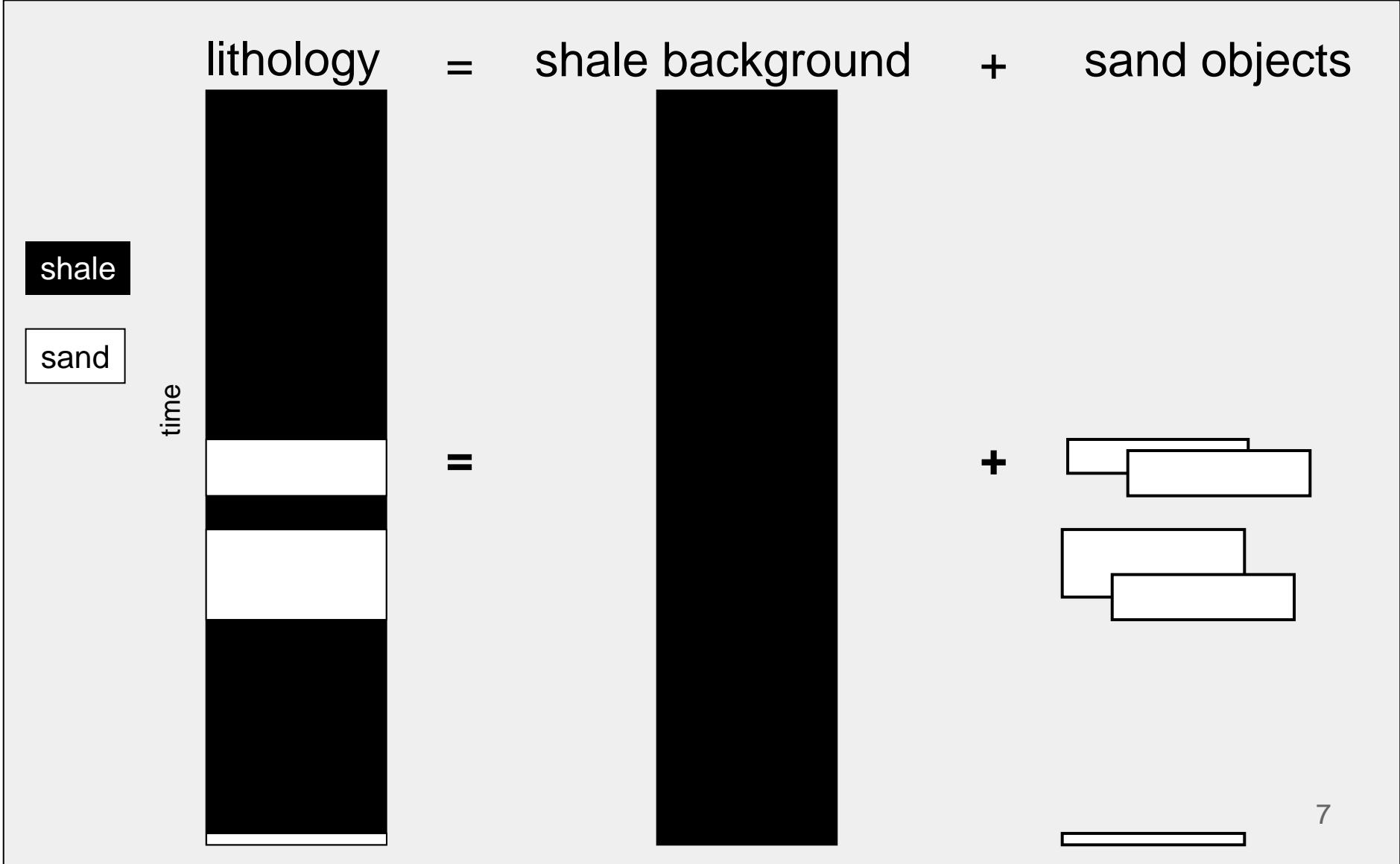
posterior

likelihood

prior

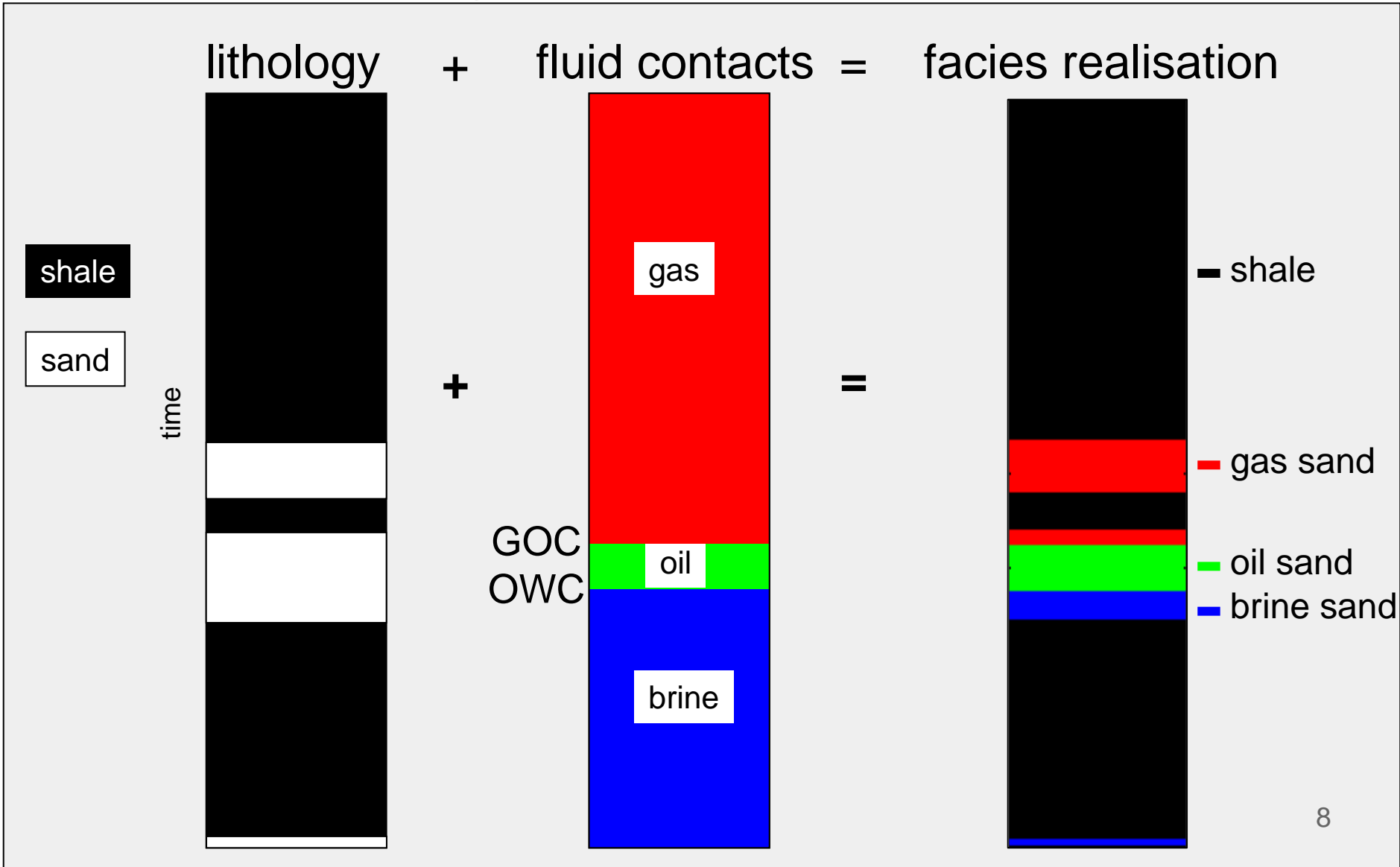


# Prior lithology model





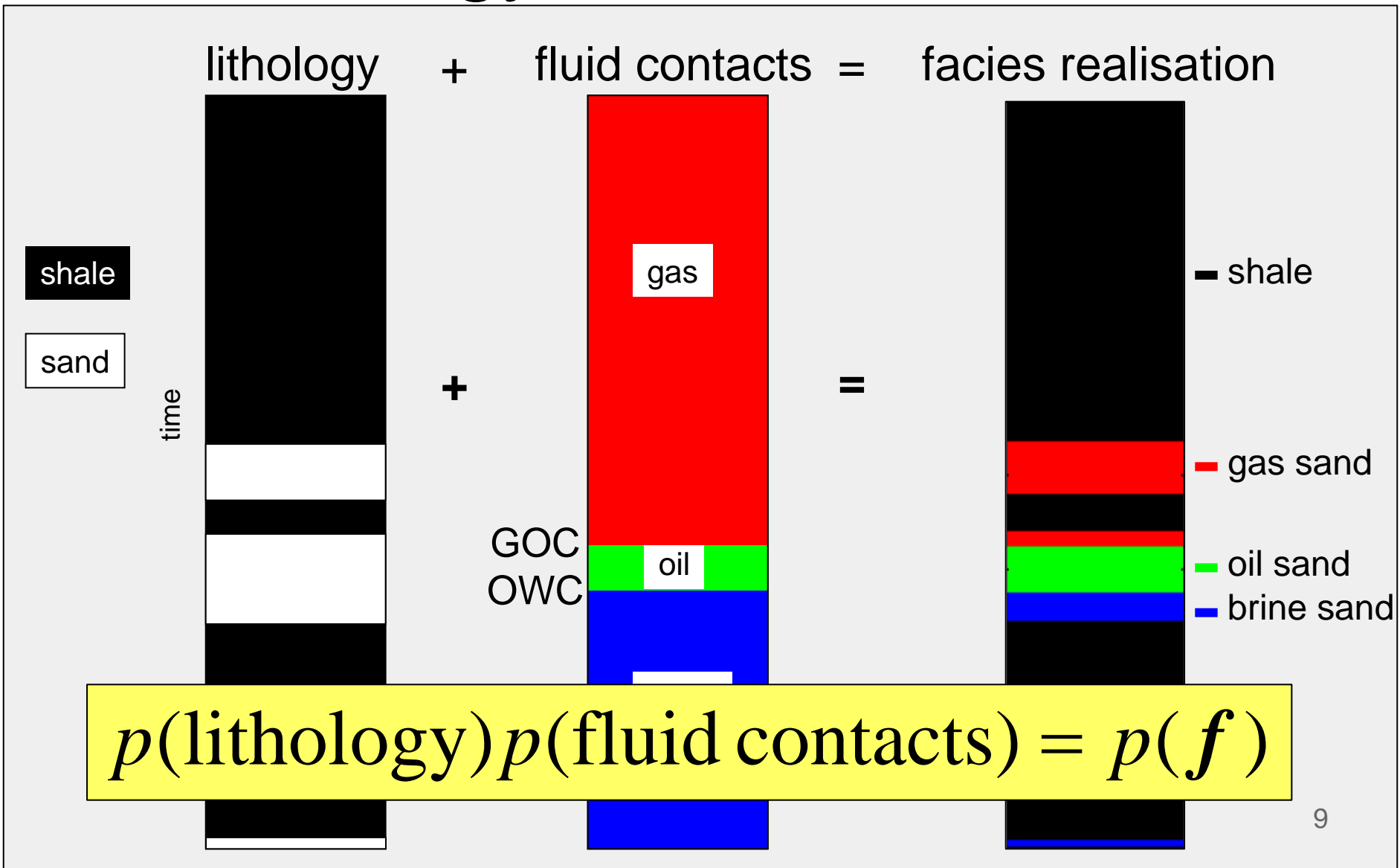
# Prior lithology-fluid model







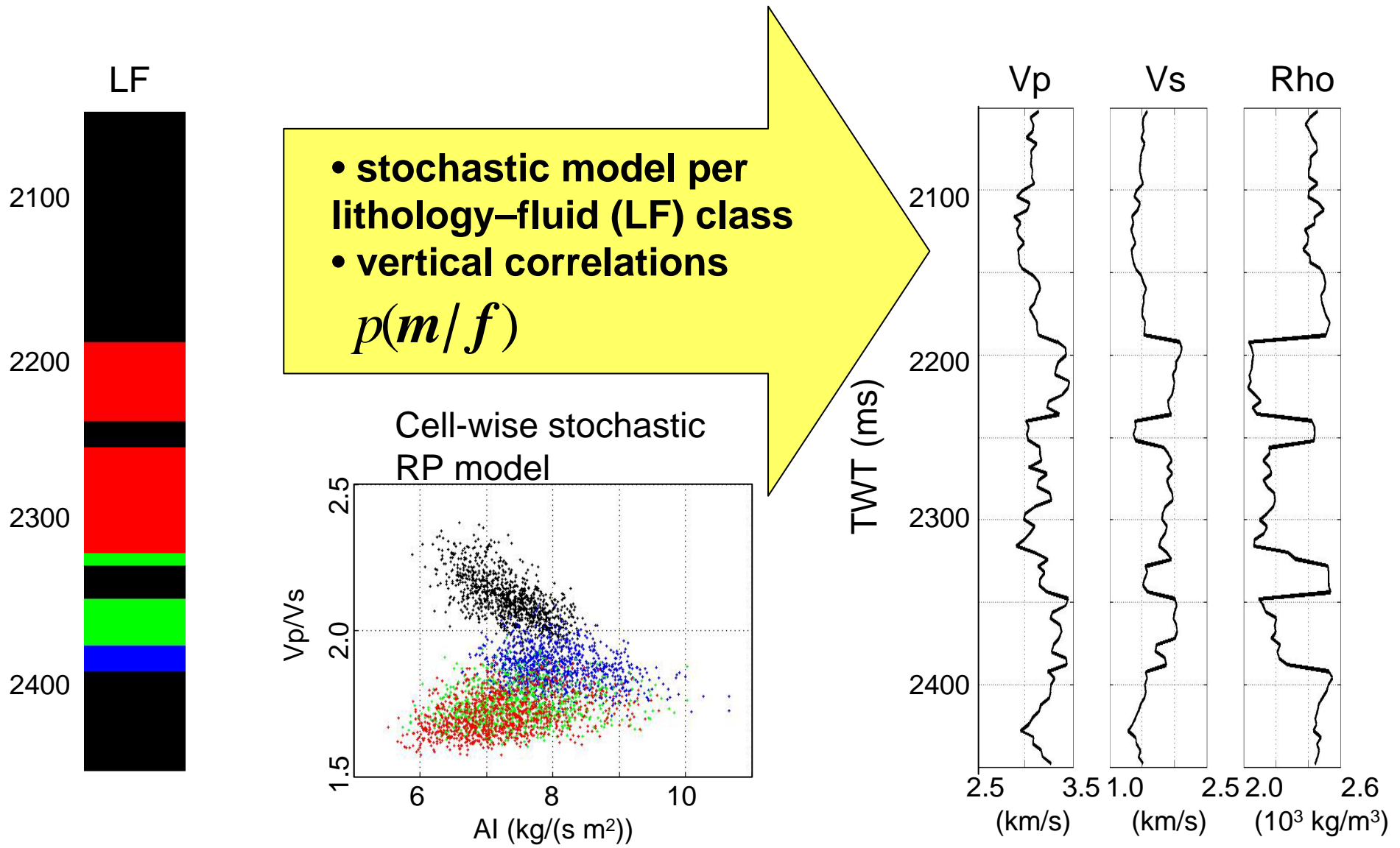
# Prior lithology-fluid model





$$p(m/f)$$

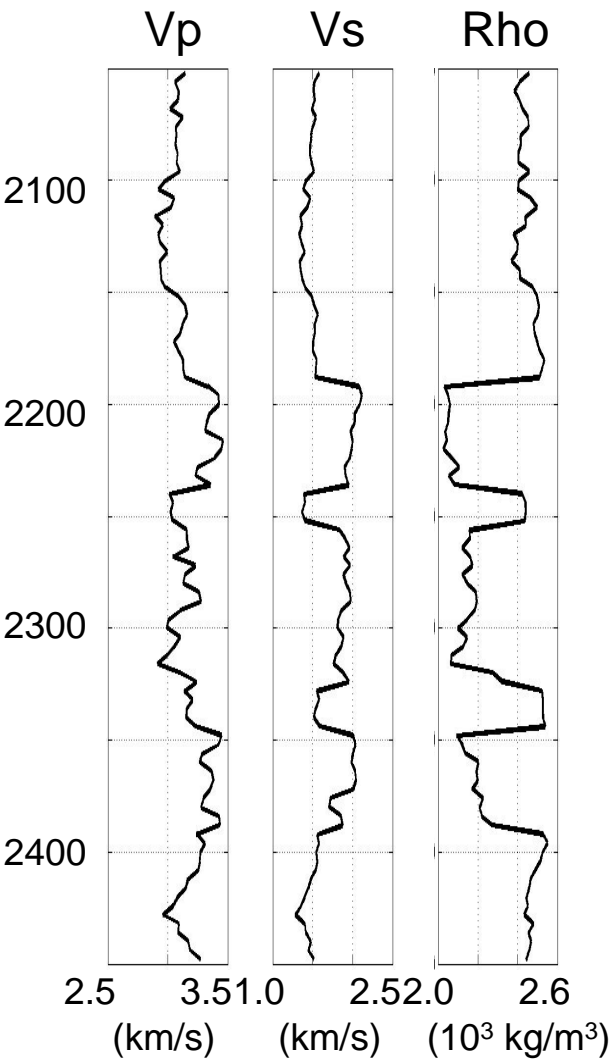
# Prior rock physics model





$$p(d | f, m)$$

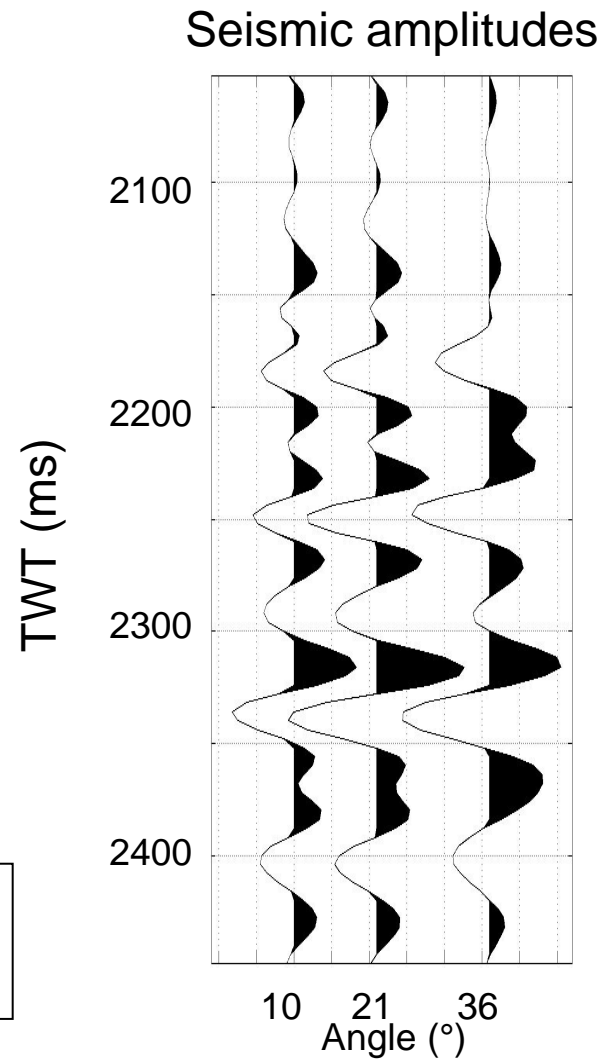
# Likelihood



• linear Aki & Richards  
 • convolution model  
 $d = Gm + e$

$$p(d | f, m)$$

Buland and Omre, 2003, *Bayesian linearized AVO inversion: Geophysics*, **68**, 185-198





# Posterior

$$p(\mathbf{f}, \mathbf{m} | \mathbf{d}) \propto p(\mathbf{d} | \mathbf{f}, \mathbf{m}) p(\mathbf{m} | \mathbf{f}) p(\mathbf{f})$$

posterior

likelihood

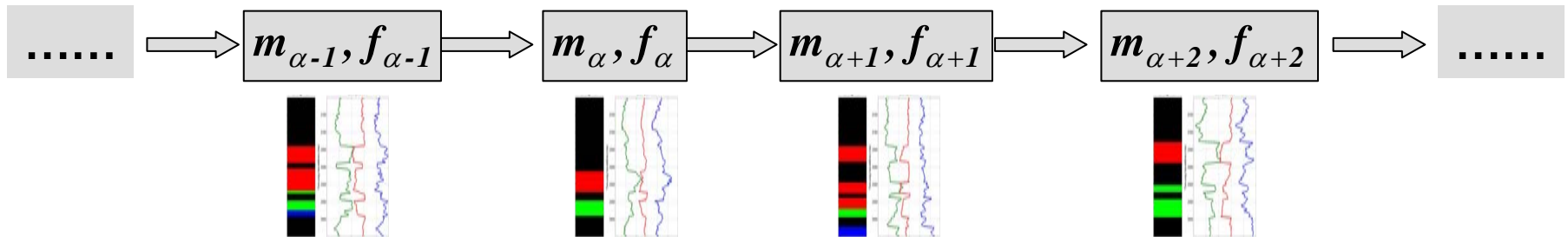
prior

- Compute volumes and discovery probabilities from posterior
- Posterior not available on analytic form
- **Construct sampling algorithm**



# Sampling posterior

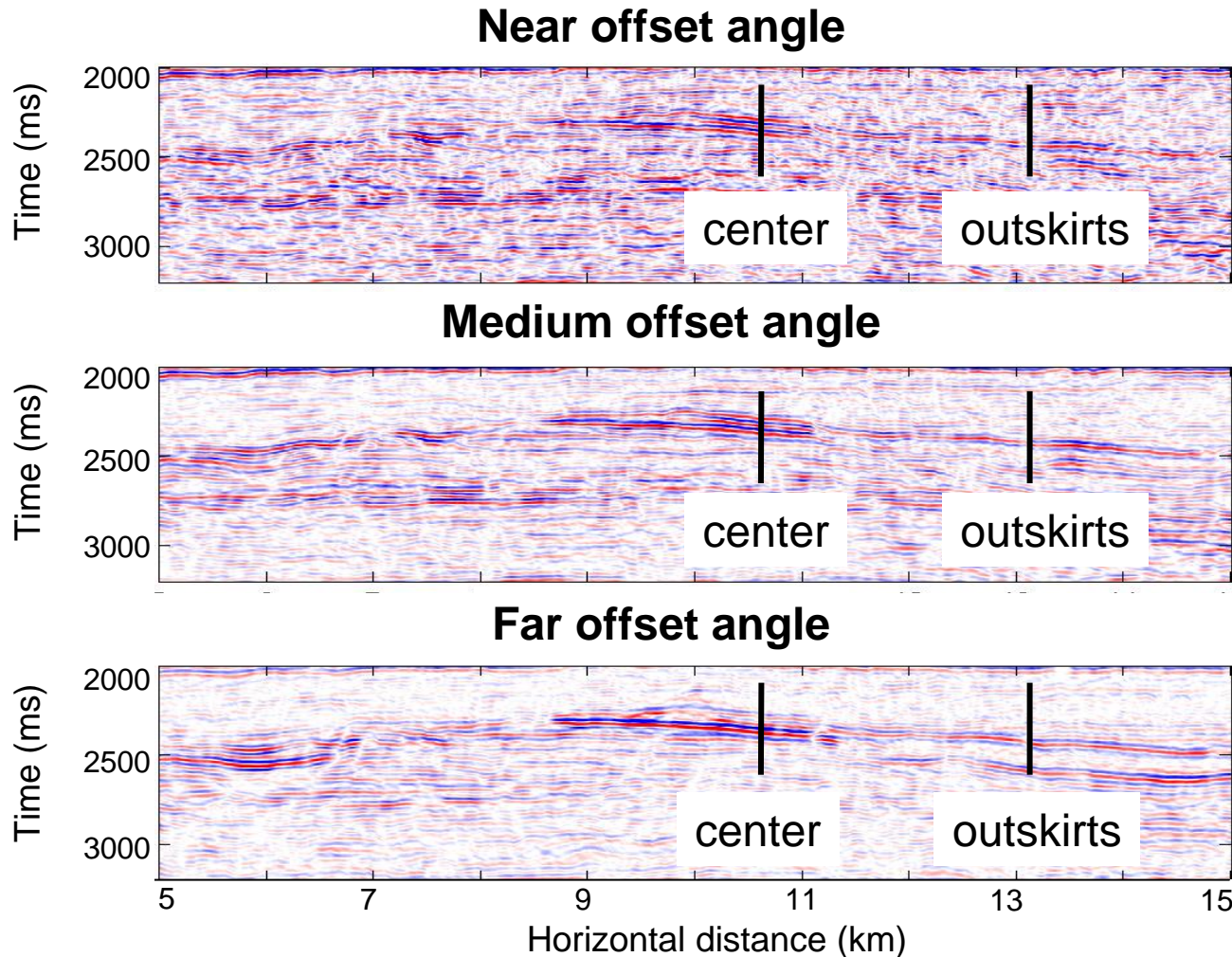
- Markov chain Monte Carlo method
  - iterative algorithm
  - generates samples of lithology–fluid and elastic parameters
  - tailor made sample generation



- Observe regularly
  - lithology–fluid
  - volumes and porosity



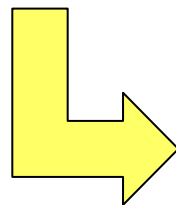
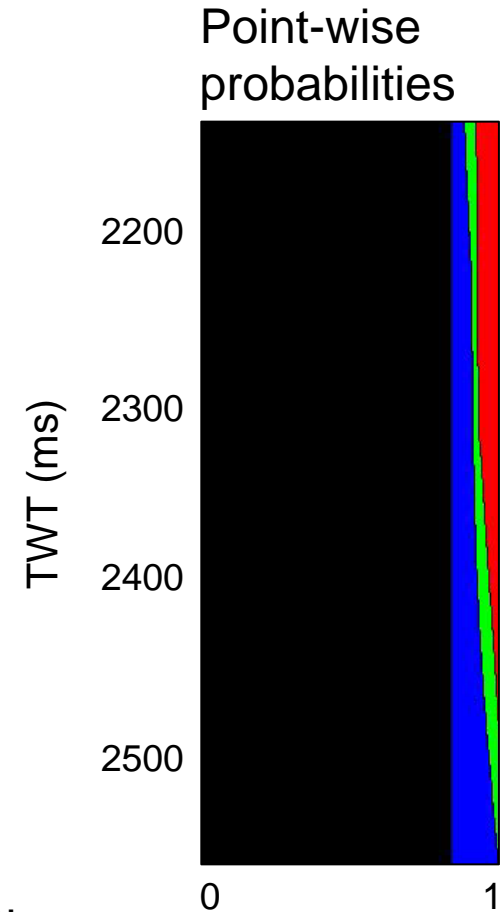
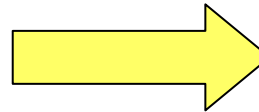
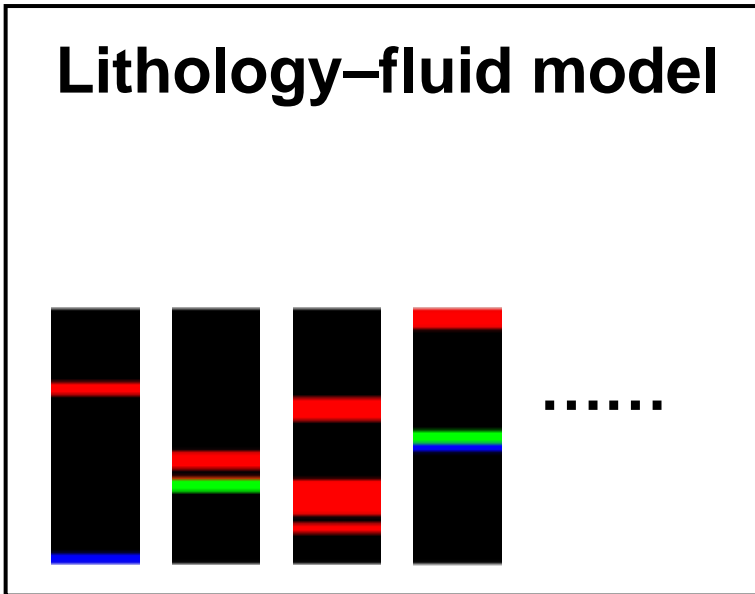
# Case study. Seismic data from prospect





# Case study.

## Lithology–fluid prior



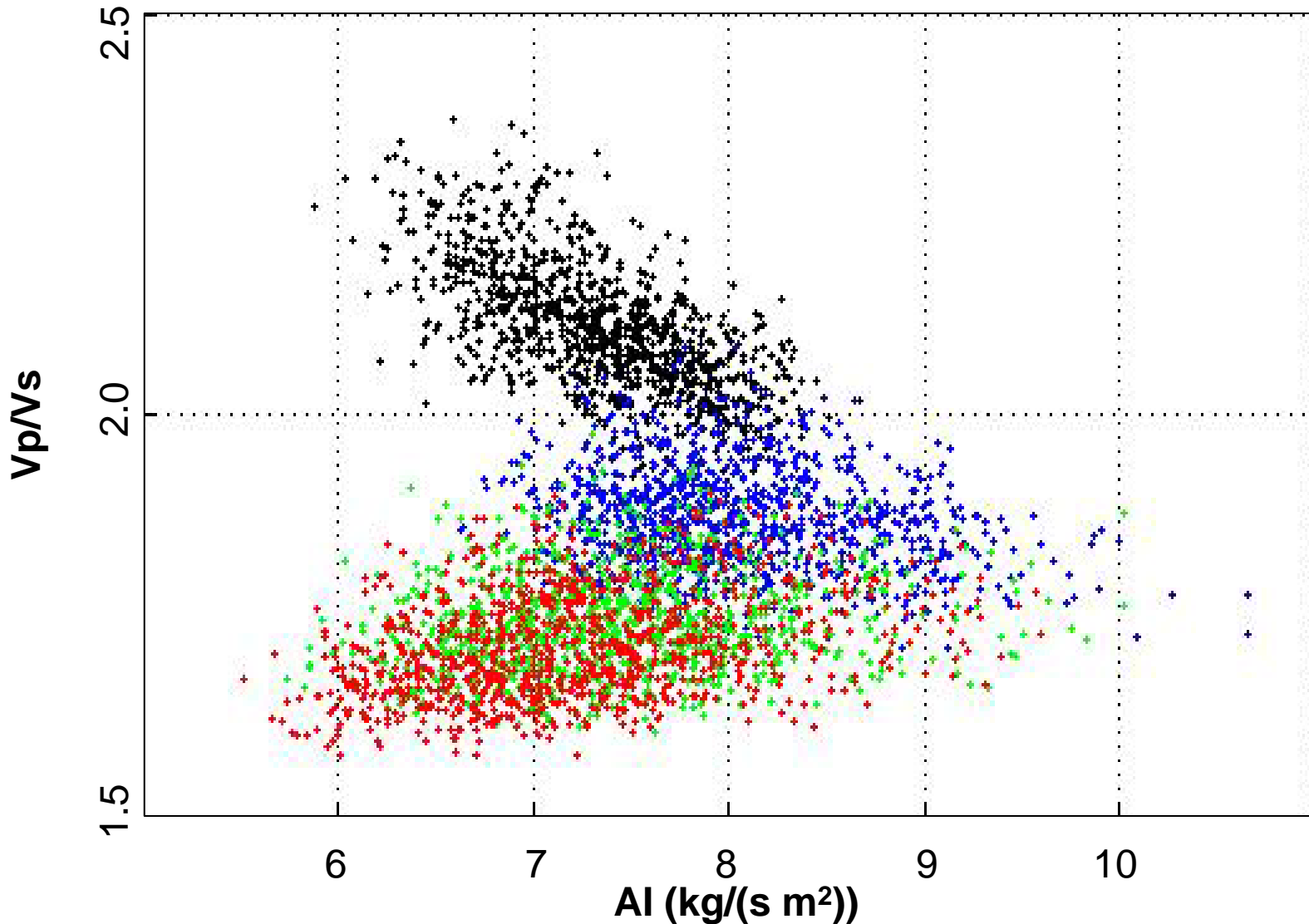
Discovery probabilities

Prior:  $P(V > 0) = 0.53$

	No HC	Oil	Gas	Gas and Oil
Prior	0.47	0.18	0.20	0.15



# Case study. Rock physics prior

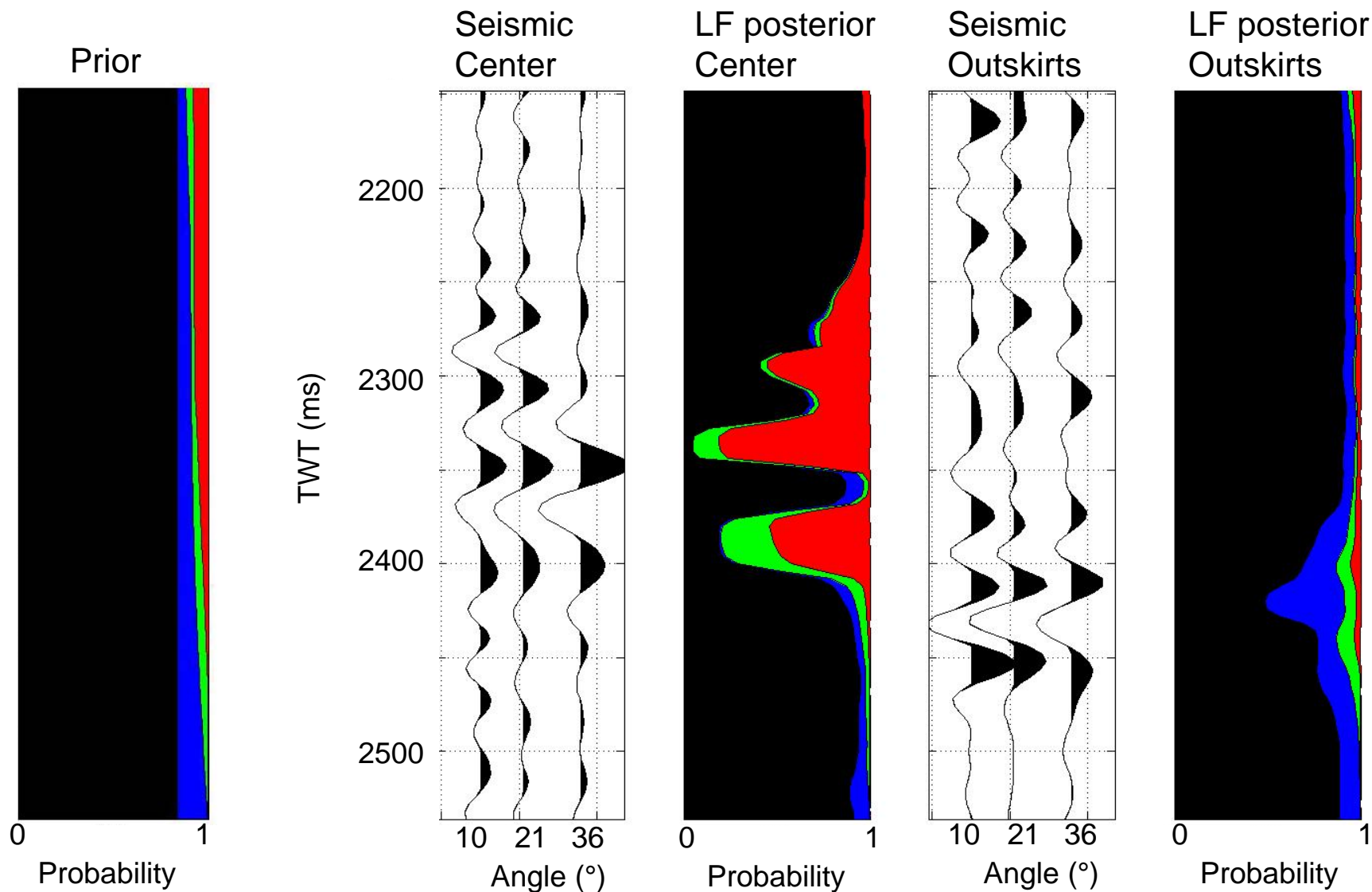






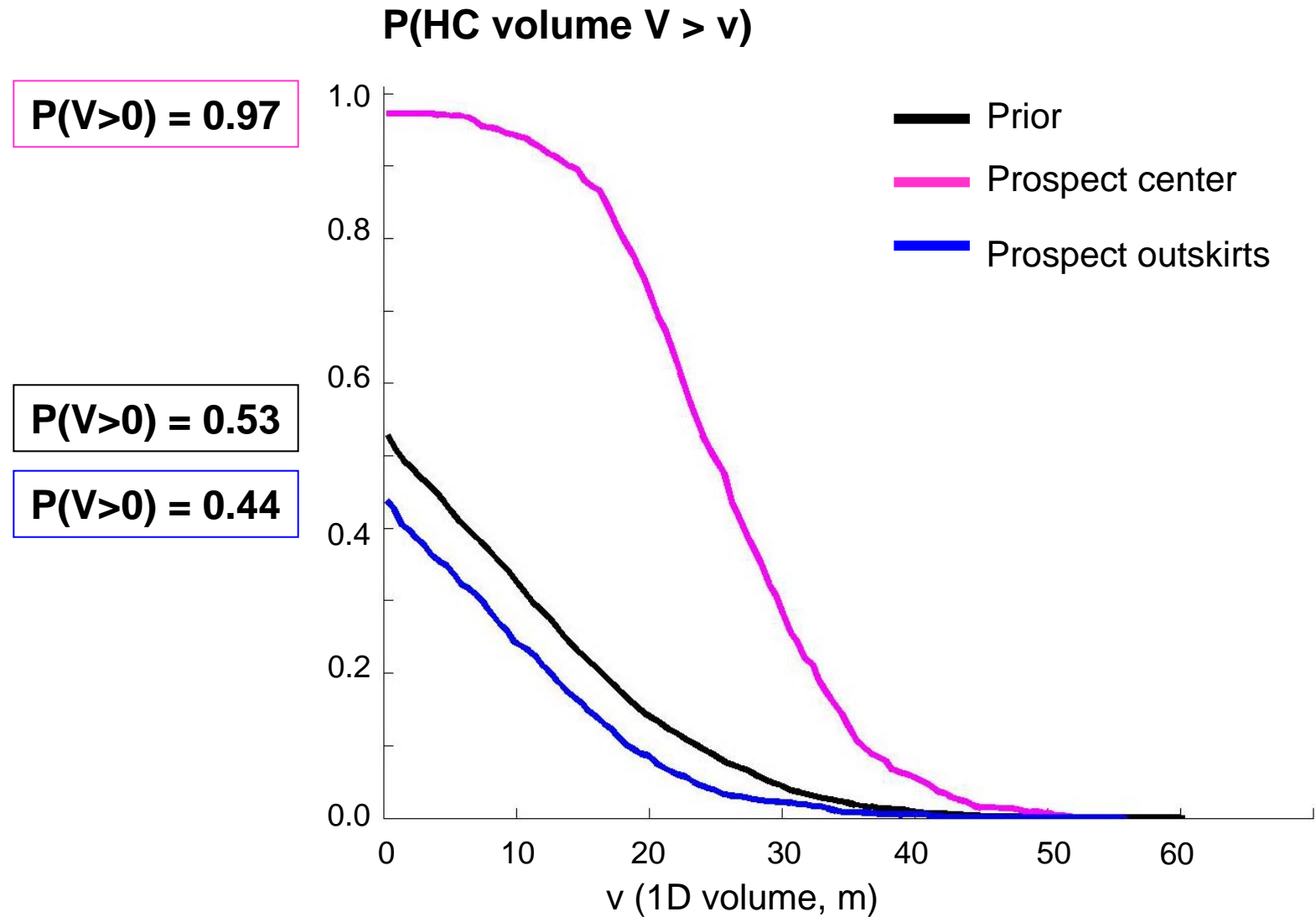
# Lithology–fluid results

- shale
- gas sand
- oil sand
- brine sand





# Volumes and discovery probability

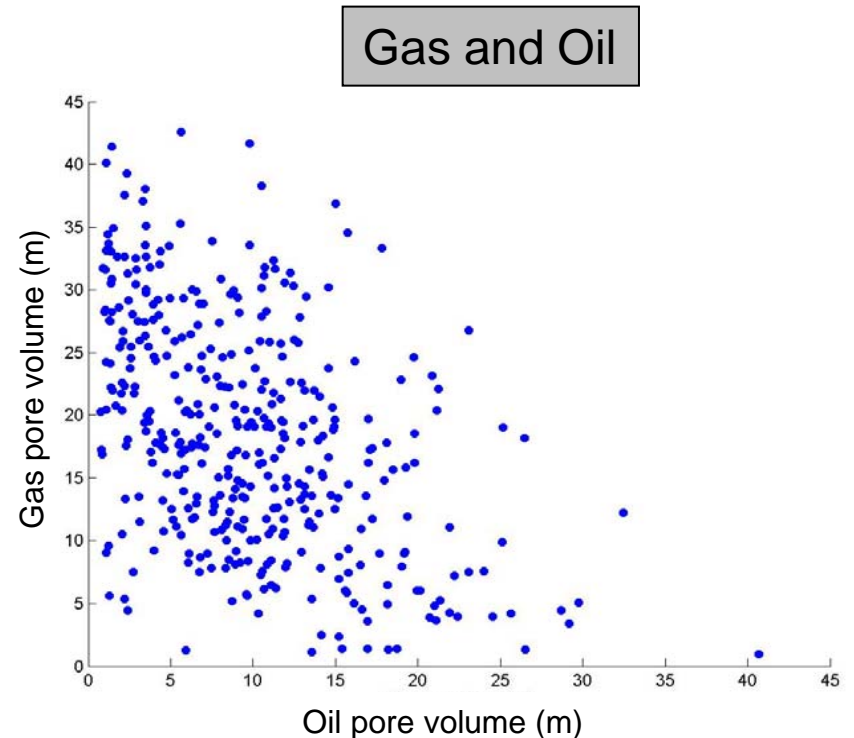
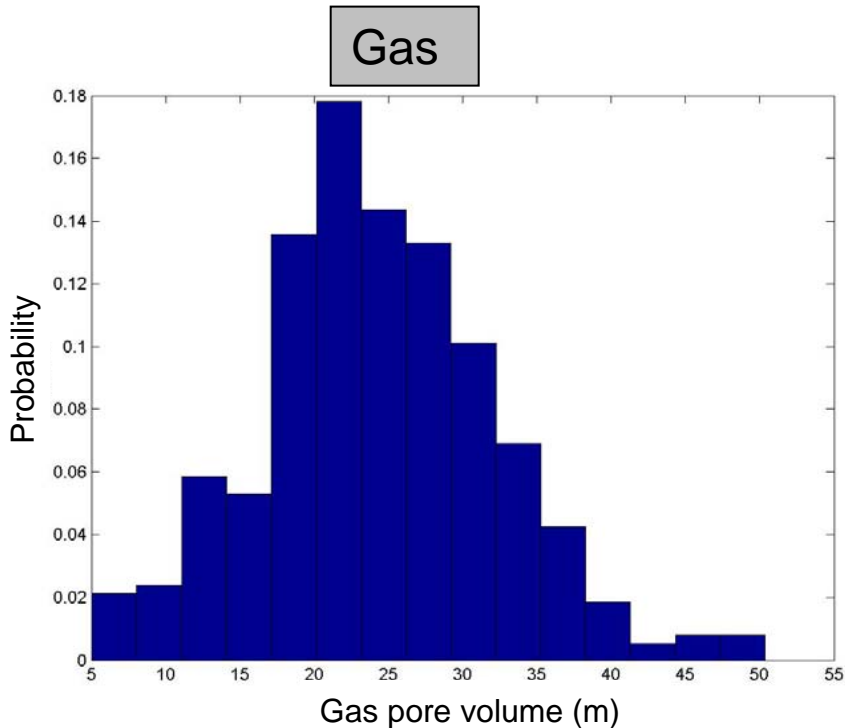




# Oil and gas scenarios at prospect center

Discovery probabilities

	No HC	Oil	Gas	Gas and Oil
Prior	0.47	0.18	0.20	0.15
Prospect center	0.03	0.06	0.45	0.46





# Concluding remarks

- Pre-drill assessment of well locations
- Realistic modeling
  - seismic amplitudes
  - rock physics
  - vertical continuity in lithology–fluid and elastic parameters
  - correct ordering of fluids
- Gives realistic results
  - probability of discovery
  - hydrocarbon volumes



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Statistics for Innovation