Is the seismic sensitive to floating grain fraction (i.e., permeability)?

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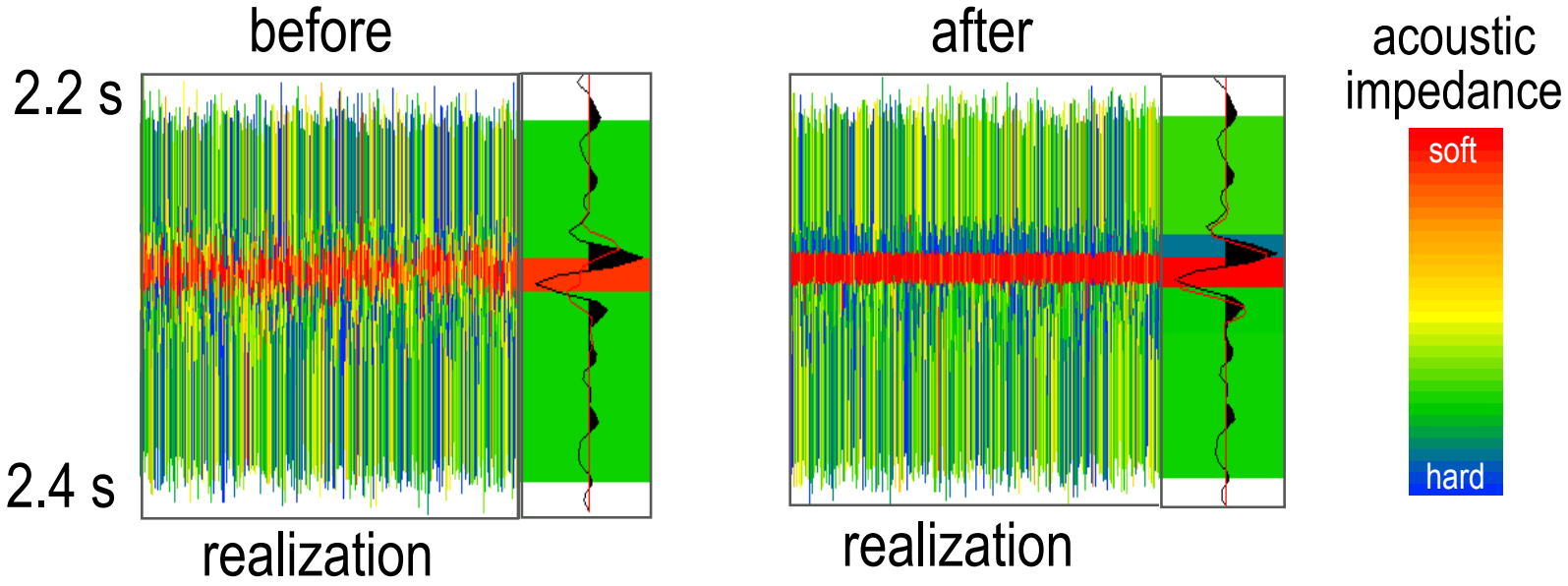
Outline

- What is probabilistic model based inversion (DELIVERY)?
- How is the floating grain model implemented in DELIVERY?
- What is the proper prior distribution of porosity and floating grain fraction?
- What can be determined for the case of a simple reflector?
- Does this hold true for a more complicated example?

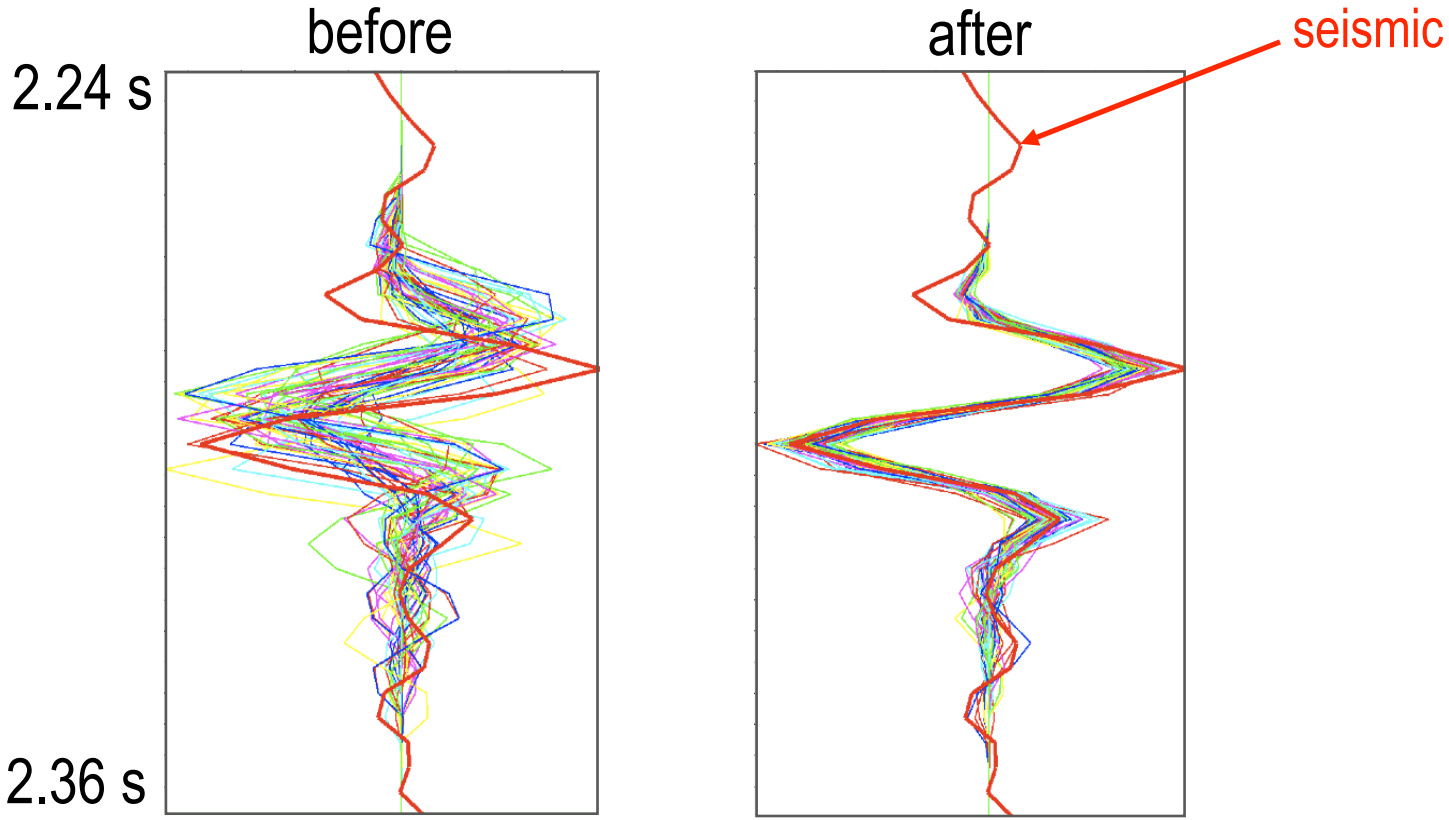
Probabilistic model based inversion

- 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)
  - floating grain fraction
  - layer top and base
  - fluid type
- Ensemble of models generated that are consistent with seismic to within estimated noise level

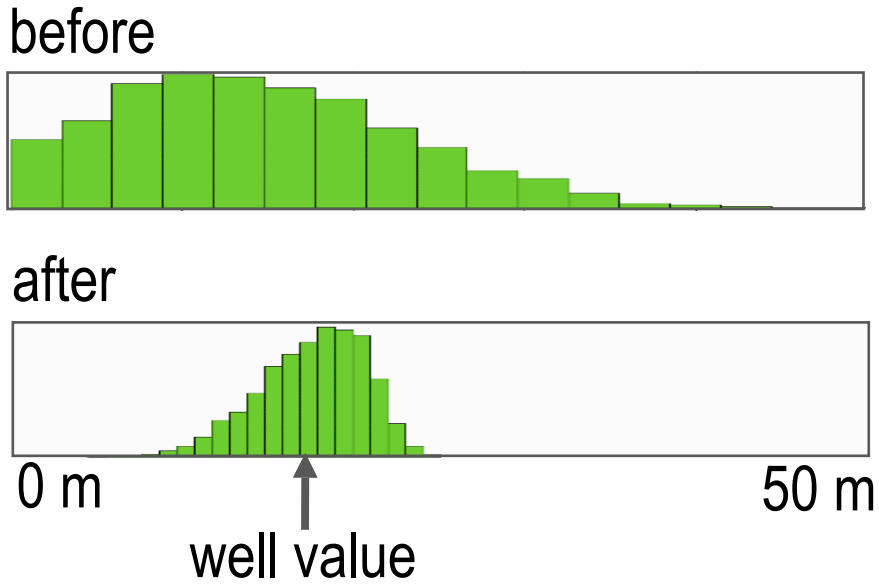
Ensemble of models show effect of model based inversion



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

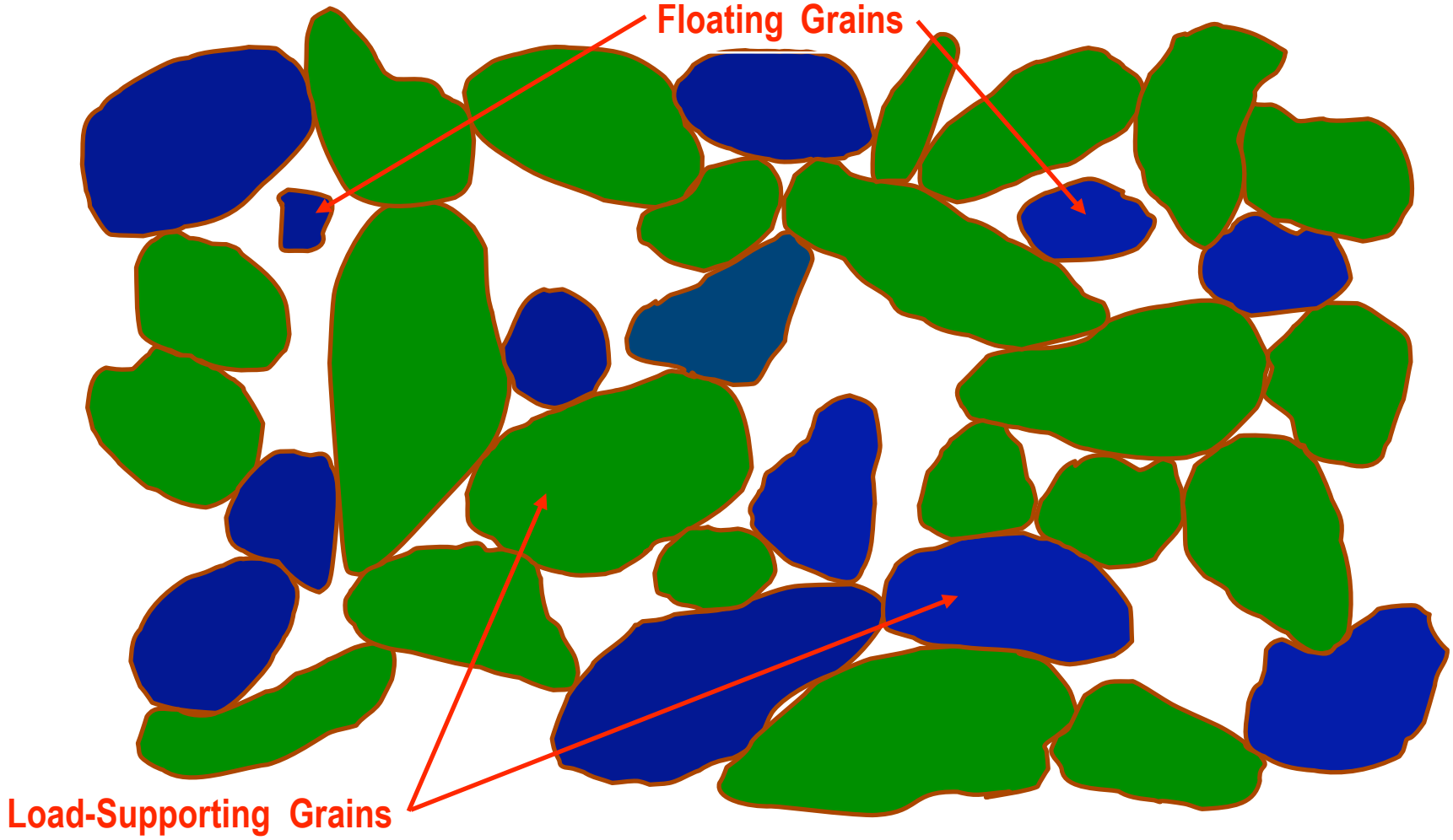


Inversion tightens the range of possible net sand

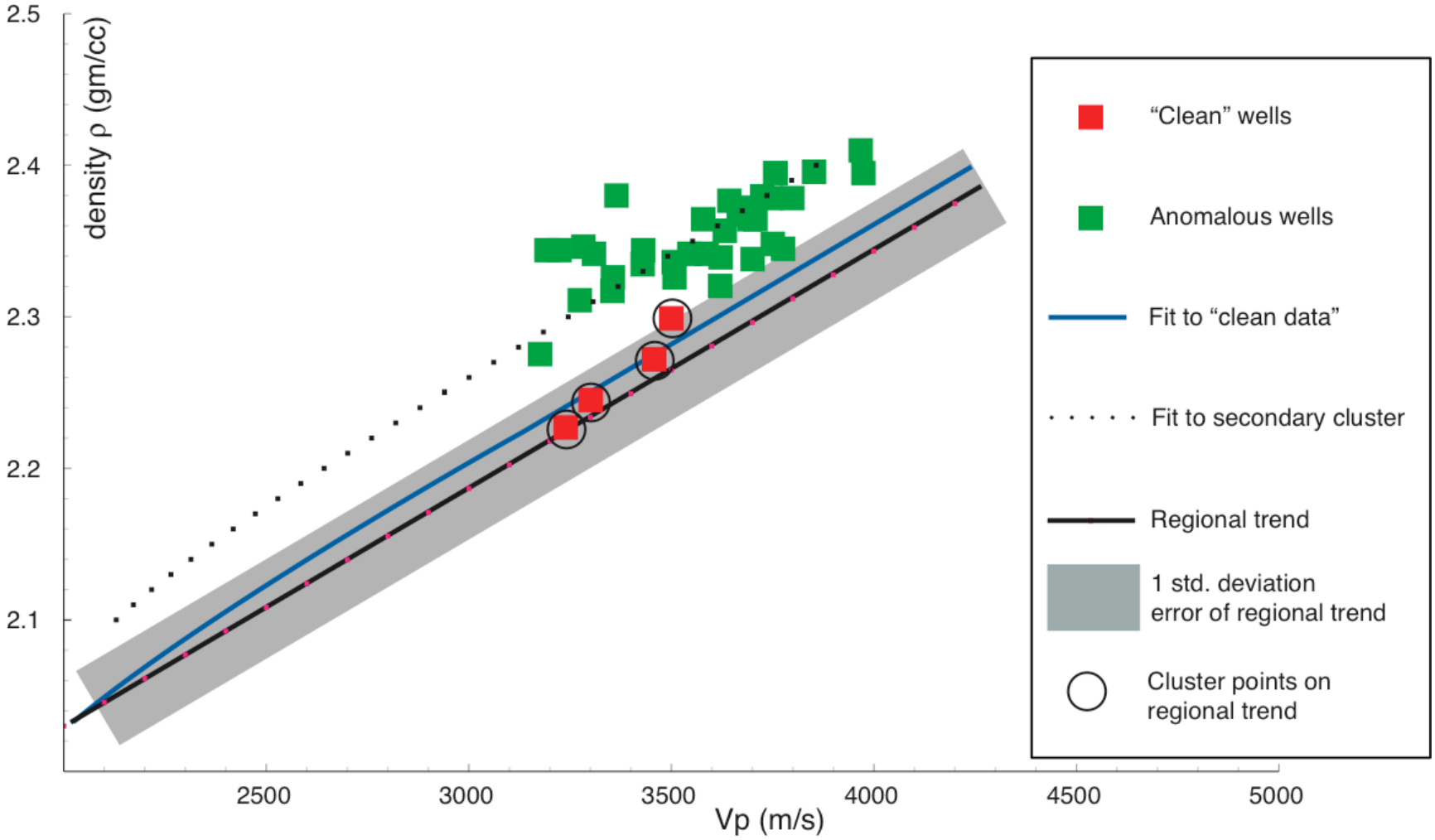


probability of oil increased to 97% from 50% (oil in sand at this location)

Picture of floating grain model



Poorly sorted sands show different behavior than well sorted sands



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Implementation of floating grain model in DELIVERY

$$v_p^2(\phi_{flt},\lambda) = \frac{K_g}{\rho_g(1-\phi)+\rho_f\phi}\left(\frac{3(1-\nu)}{(1+\nu)}(1-(\phi+\phi_{flt})/\phi_0)^{\lambda} + \frac{(1-(1-(\phi+\phi_{flt})/\phi_0)^{\lambda})^2}{\phi(K_g/K_f-1)+1-(1-(\phi+\phi_{flt})/\phi_0)^{\lambda}}\right)$$

- $\phi = A_\phi + B_\phi\, v_p + C_\phi \phi_{flt} + \varepsilon_\phi$
  - *(from numerical inversion of above, using clusters)*
- $v_p = A_p + B_p d + C_p\, LFIV + D_p\, \phi_{flt} + \varepsilon_p$
  - *(inverted from this regression, direct from log data and clusters)*

  $\phi = A' + B'd + C'\phi_{flt} + \varepsilon_{\phi'}$ *with* $d \leftarrow (1-\exp(-\sigma_{eff}/P_0))$

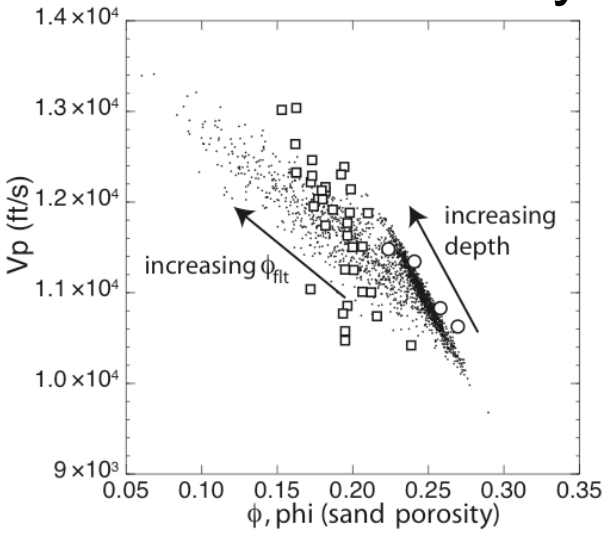
  $C = -1/(1-f_c)$, f_c *a 'capture fraction'*
- $V_s = A_s + B_s\, v_p + \varepsilon_s$

  - *direct from log data*

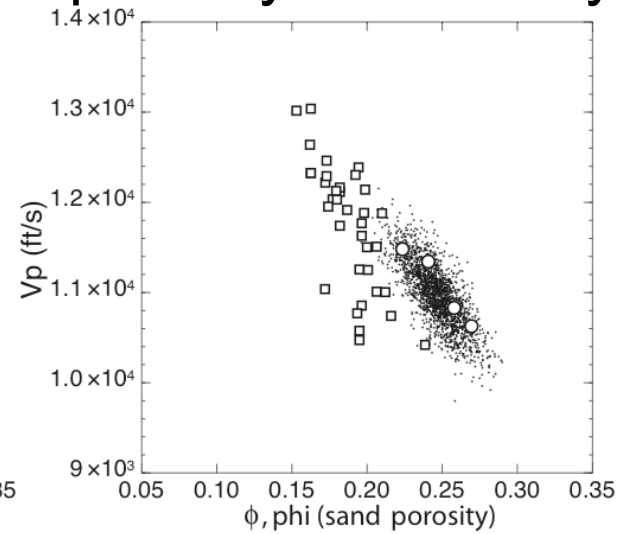
Porosity and float fraction uncertainty needed to match vp-phi scatter of wells

bhpbilliton

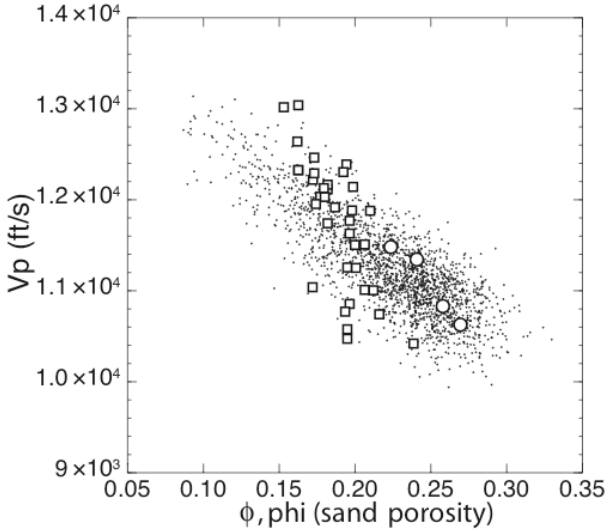
float uncertainty



porosity uncertainty



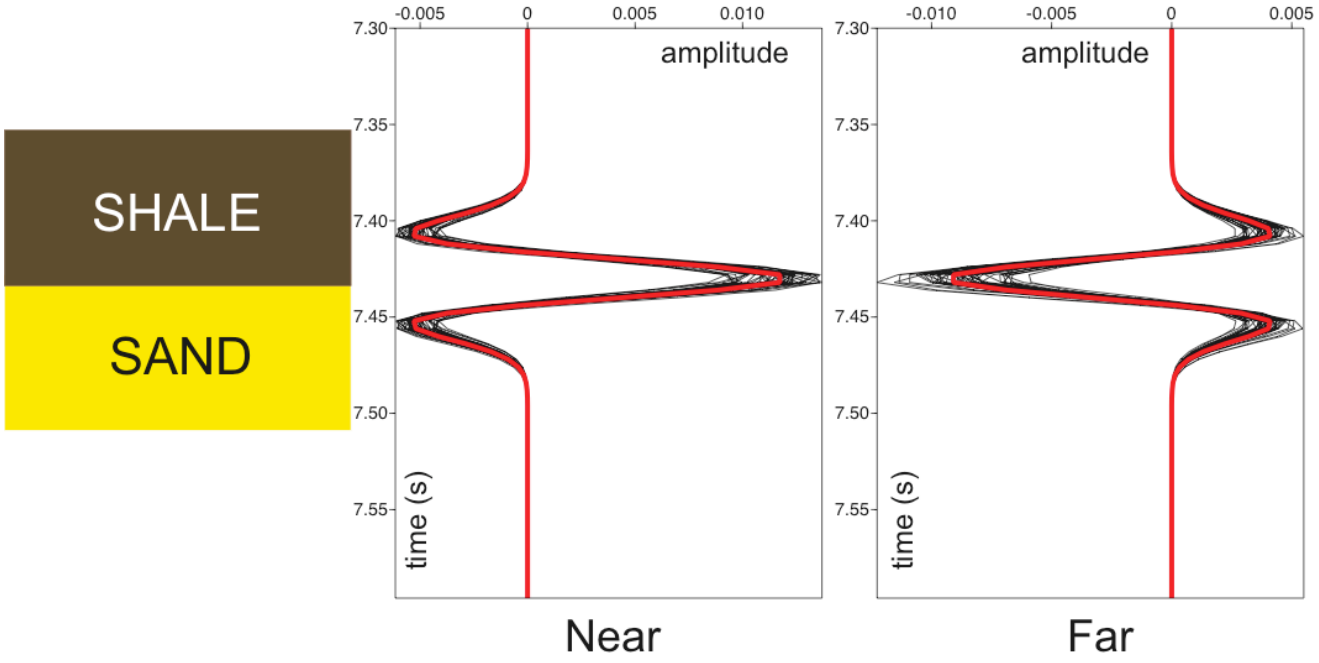
both



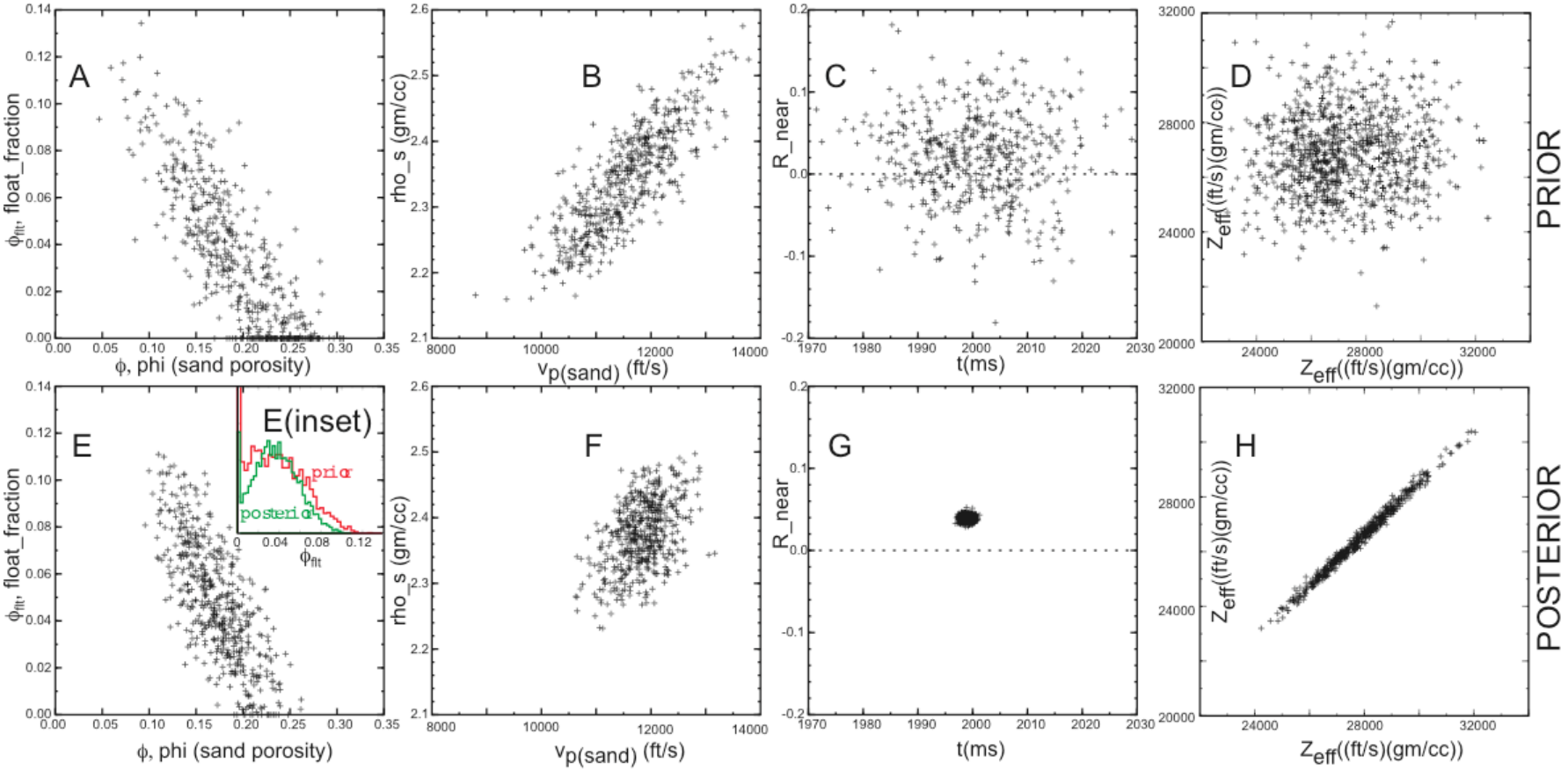
note: circles are well sorted sands, squares are poorly sorted

Single reflector model

- Seismic 35 Hz
- Near (0^0) and far (30^0) stacks



Distributions become tighter because of seismic constraints (fixed N/G)



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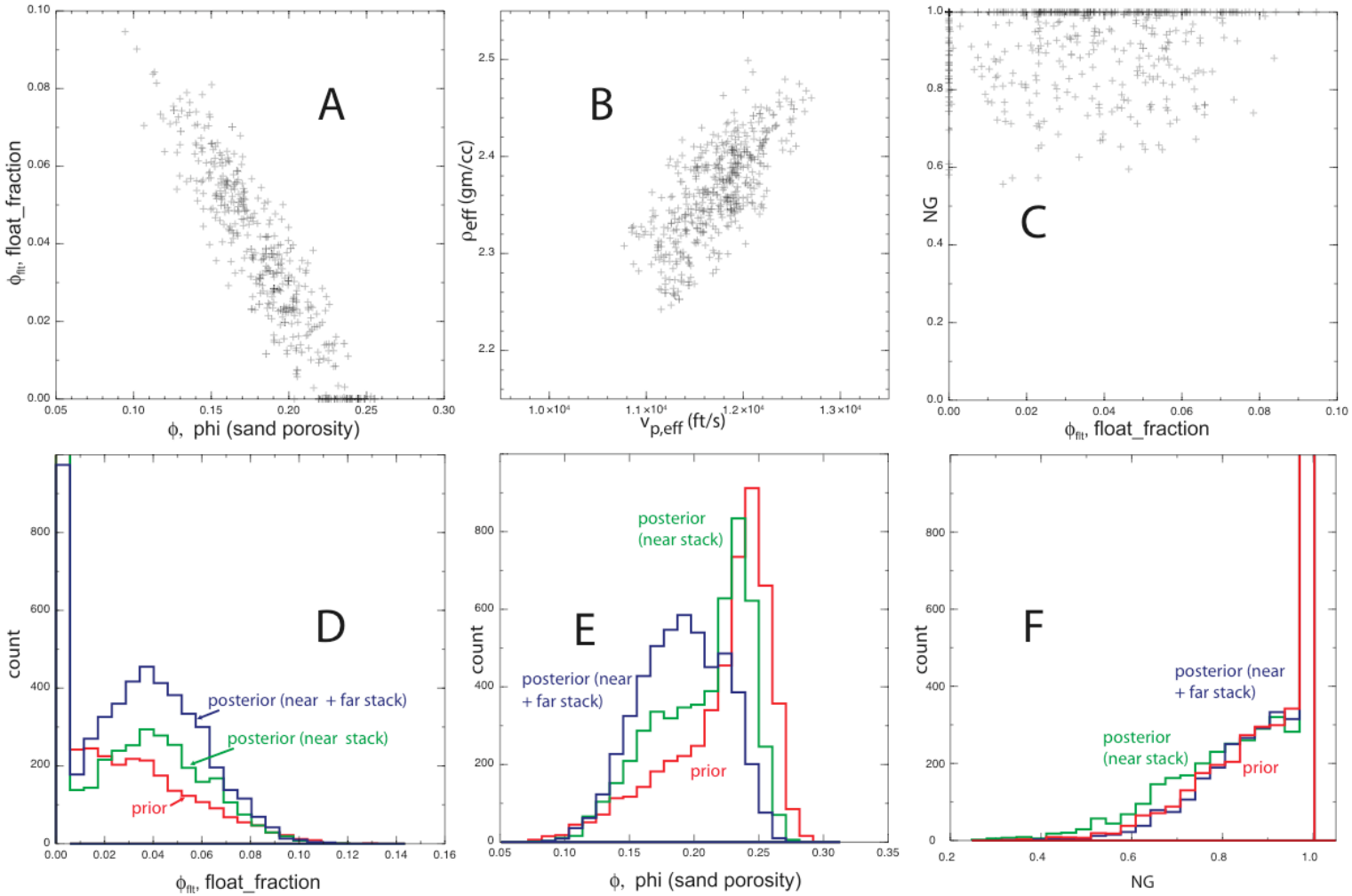
Floating grain and porosity, not N/G, is sensitive to seismic



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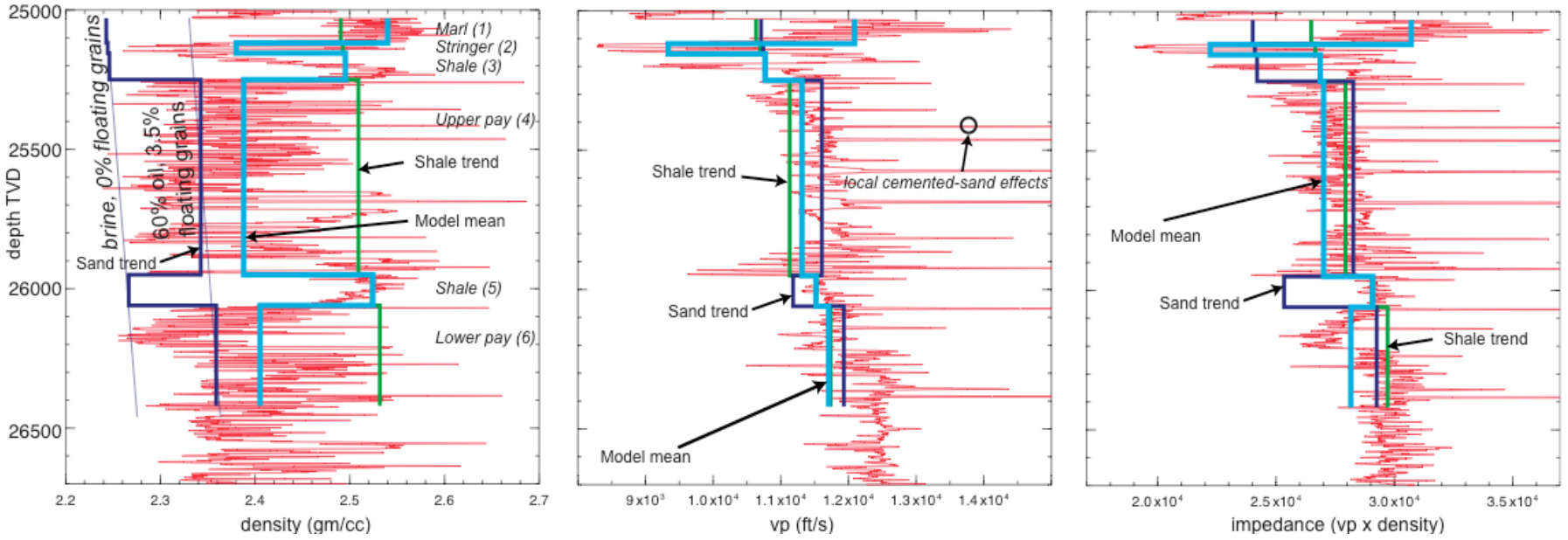
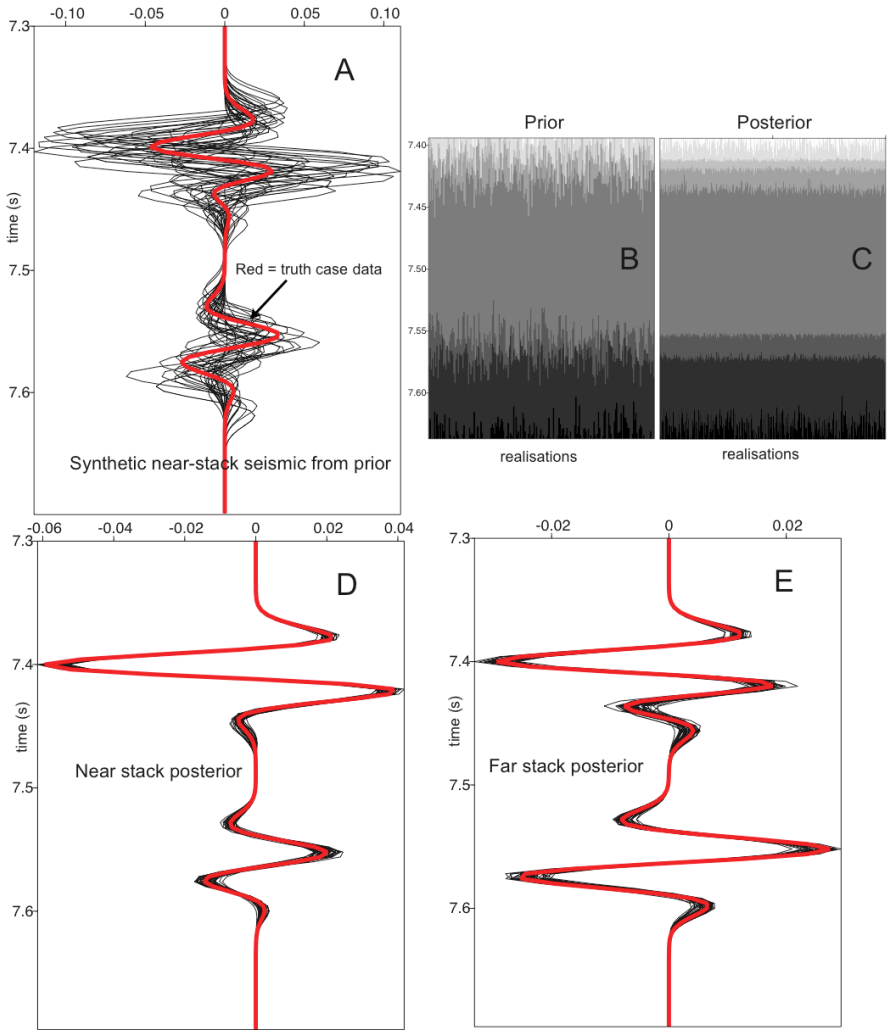
Realistic example



Multiple stack inversion results



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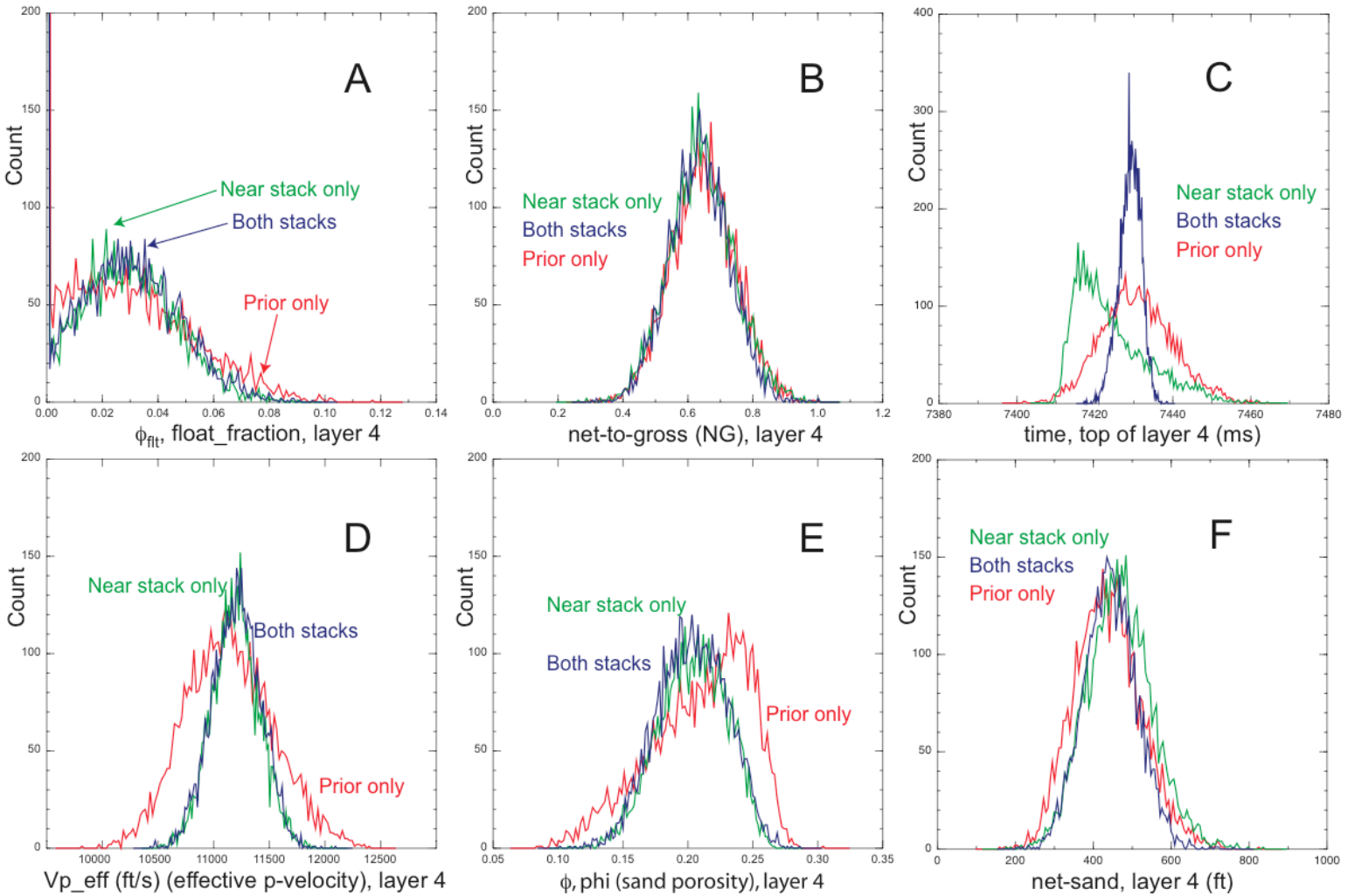
Sensitivity of properties to seismic amplitudes and AVO



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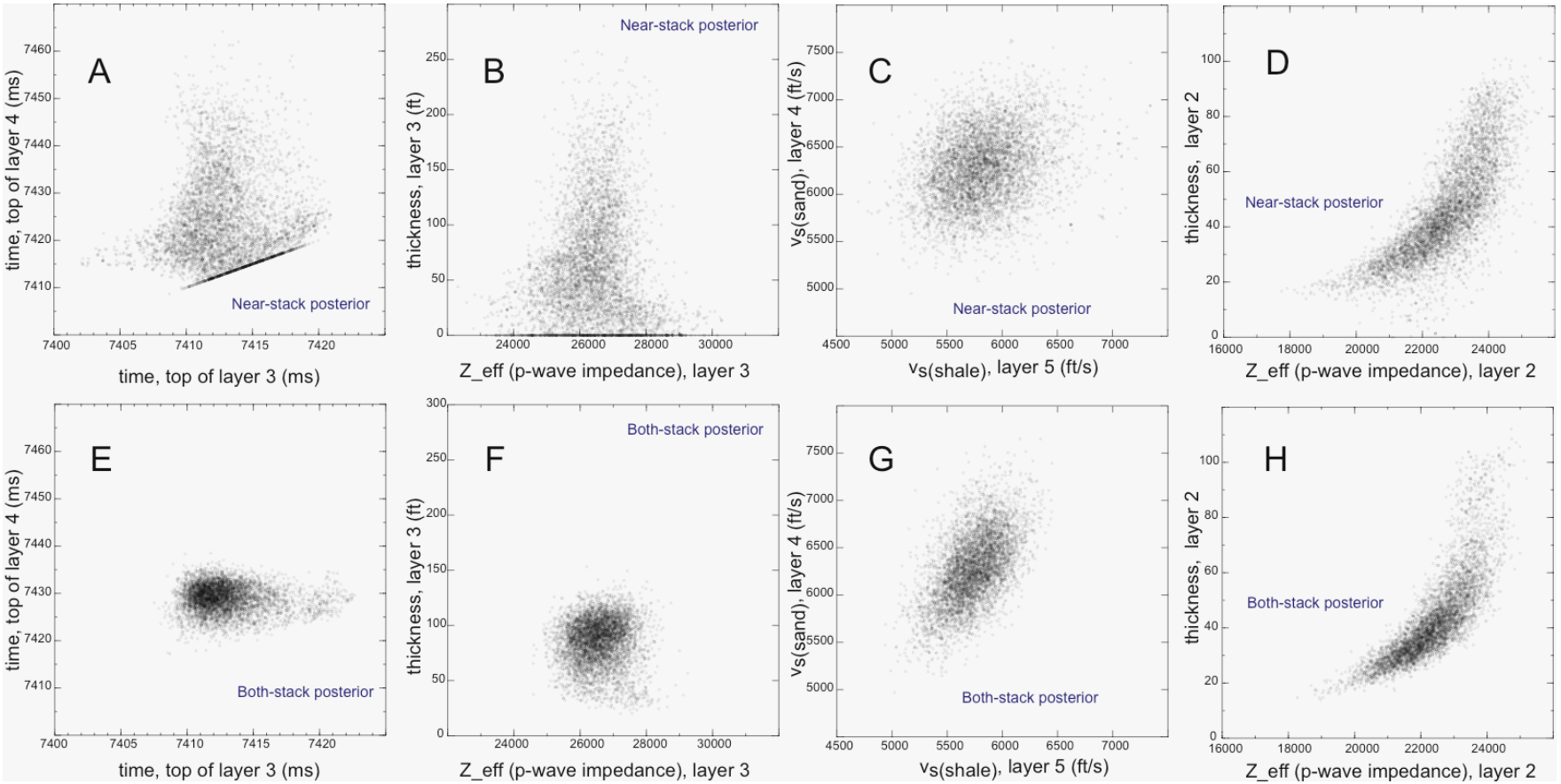
Additional correlation is determined by AVO



layer 2 = stringer
layer 3 = shale
layer 4 = upper sand
layer 5 = shale

Conclusions

- floating grain fraction and porosity can be determined by seismic response, therefore permeability
- N/G can not be determined
- AVO is not much help with quantities of interest