



## **Ram/Powell PROMISE results**

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# Statistical inversion solves for probability of model



**petrophysics**  
(trend curves,  
neural networks)

$P(m|d_{\text{petro}})$  = probability of model given  
petrophysical data

**seismic**

$q_{<n>}(n)$  = noise distribution  
 $= \exp(-\sum n_k^2 / <n_k>^2)$

$s(m)$  = synthetic seismic given model  
(forward modeling)

$d_{\text{seismic}}$  = seismic data

$\Rightarrow P(d_{\text{seismic}}|m) = q_{<n>}(d-s(m))$   
= probability of seismic  
given the model

$$P(m|d_{\text{seismic}}, d_{\text{petro}}) \sim P(d_{\text{seismic}} | m) P(m | d_{\text{petro}})$$

# Iterative solution for N equally probable models



construct a sequence  $\{ P_n(m) \}$  such that

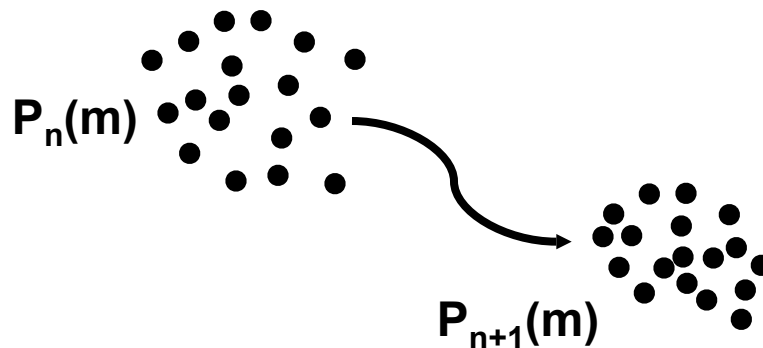
$$P_n(m) \xrightarrow{R} P(m | d) \quad \text{as } n \xrightarrow{R} \infty,$$

$$P_0(m) = P(m),$$

and

$$P_{n+1}(m) = F( P_n(m) )$$

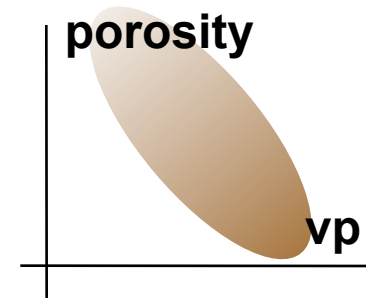
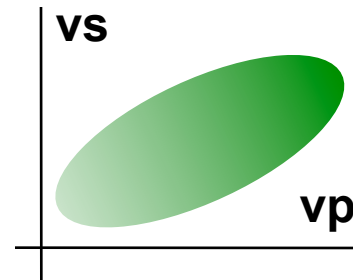
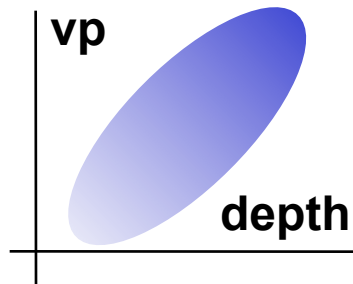
$F$  = conjugate gradient or metropolis



# GOM petrophysical end member trends used in prior probability

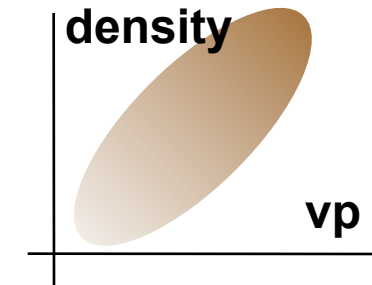
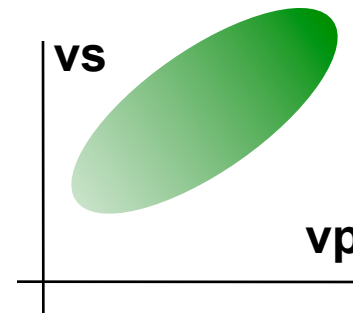
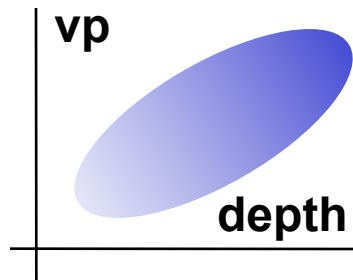


wet  
sand



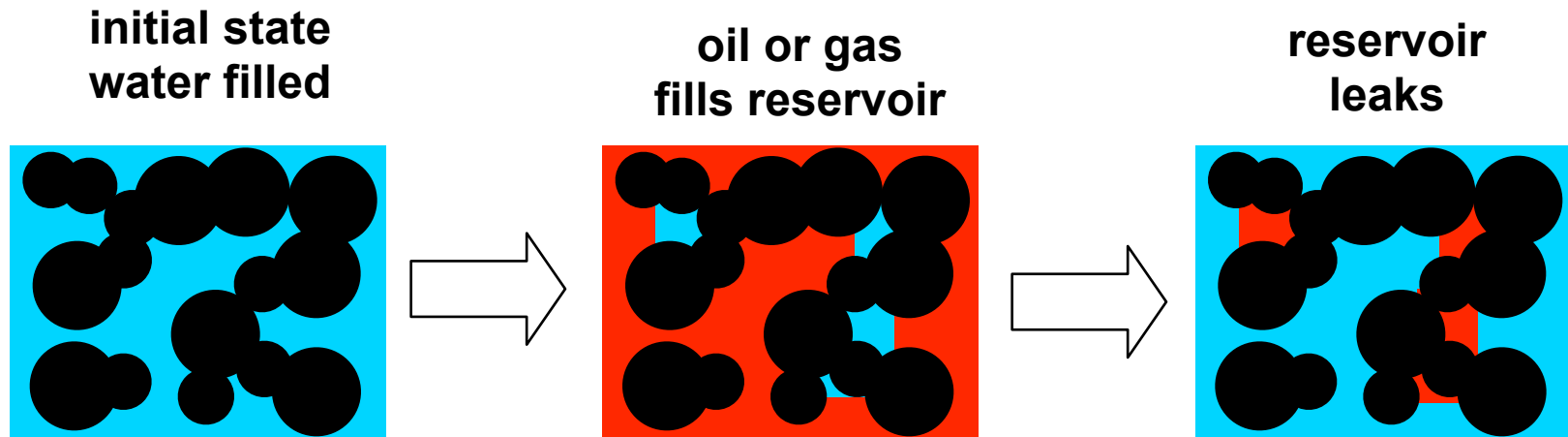
mix with net/gross  $\pm \sigma$

mud-  
stone



**note: separate trend for each layer**

# Discrete cases of fluid fill are used



- **prior probability of each fluid fill case**
  - neural network fluid prediction
  - regional information (trap probability, leak probability, etc.)
- **posterior probability of each fluid fill case**
  - adds seismic AVO information

# General information about Ram/Powell

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- **stratigraphically trapped unconfined turbidites in Eastern Gulf of Mexico**
  - J-sand is an amalgamated channel sheet sand complex
  - L-sand is channel levee
  - M-sand is channel levee to amalgamated channel
  - N-sand is massive channels
- **in 2500 to 4000 ft of water**
- **250 MMBBL equivalent**

# Some details of the inversion and petrophysics

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**clean wet sand:**

$$vp(\text{in ft/s}) = 0.1397 * D(\text{in ft}) + 7934 \quad \pm 166$$

$$vs(\text{in ft/s}) = 0.9 * vp - 3500 \quad \pm 140$$

$$\text{porosity} = -8.0595e-5 * vp + 1.0582 \quad \pm 0.016$$

**mudrock:**

$$vp = -0.0474 * D + 11265 \quad \pm 230$$

$$vs = 0.84 * vp - 3900 \quad \pm 200$$

$$\text{density}(\text{in gm/cc}) = 0.7038 * vp ^ 0.1351 \quad \pm 0.022$$

**laminated sands:**

$$\text{net/gross} \quad \pm 0.1$$

**bounding mudrock:**

$$vp = -0.0044 * D + 10308 \quad \pm 230$$

$$vs = 0.84 * vp - 3900 \quad \pm 200$$

$$\text{density} = 0.3852 * vp ^ 0.1997 \quad \pm 0.022$$

**seismic signal to noise ratio:**

**10 dB (near and far stacks)**

# More details of the inversion and petrophysics



**DepSim model constructed from:**

**2 interpreted horizons**

**12 out of 41 wells**

**(thickness & N/G)**

**constrained time horizons:**

**top J-sand (8 ms)**

**top M-sand (10 ms)**

**top N shale (10 ms)**

**constrained thicknesses:**

**J-sand (15 ft)**

**J shale (30 ft)**

**L-sand (50 ft)**

**L shale (30 ft)**

**M-sand (35 ft)**

**M shale (25 ft)**

**N-sand (25 ft)**

**gas:**

**prior probability = 0.33**

**vp = 2760 ft/s**

**density = 0.235 gm/cc**

**saturation = 85%**

**brine:**

**prior probability = 0.34**

**vp = 5278 ft/s**

**density = 1.055 gm/cc**

**oil:**

**prior probability = 0.33**

**vp = 3050 ft/s**

**density = 0.584 gm/cc**

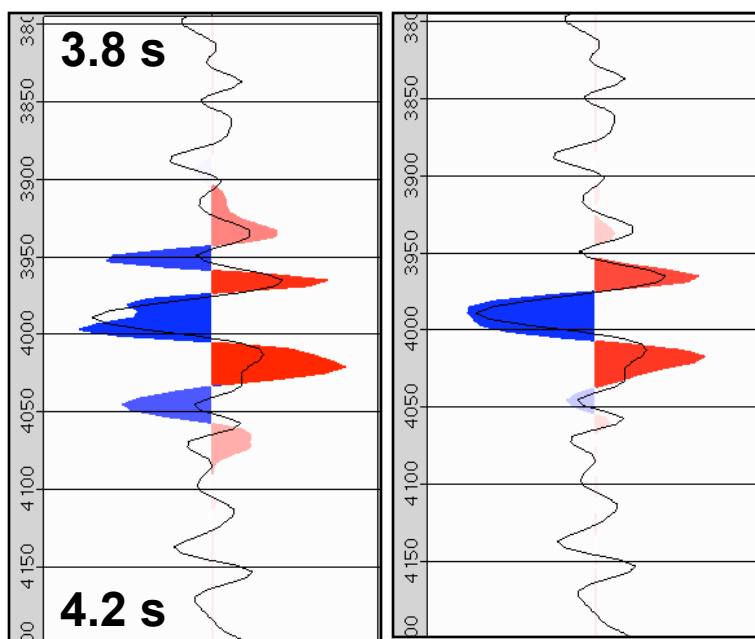
**saturation = 85%**



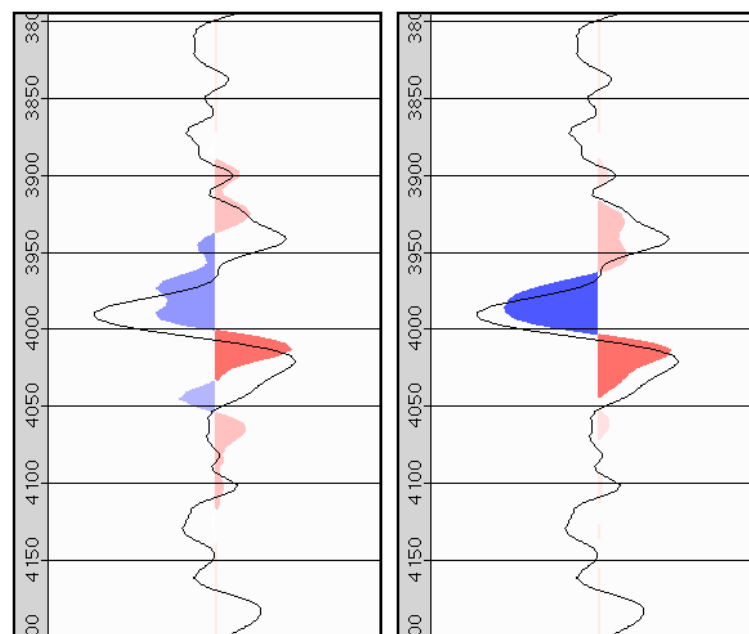
# PROMISE inversion at a well (912-2)



**near stack**  
**before inversion**    **near stack**  
**after inversion**



**far stack**  
**before inversion**    **far stack**  
**after inversion**

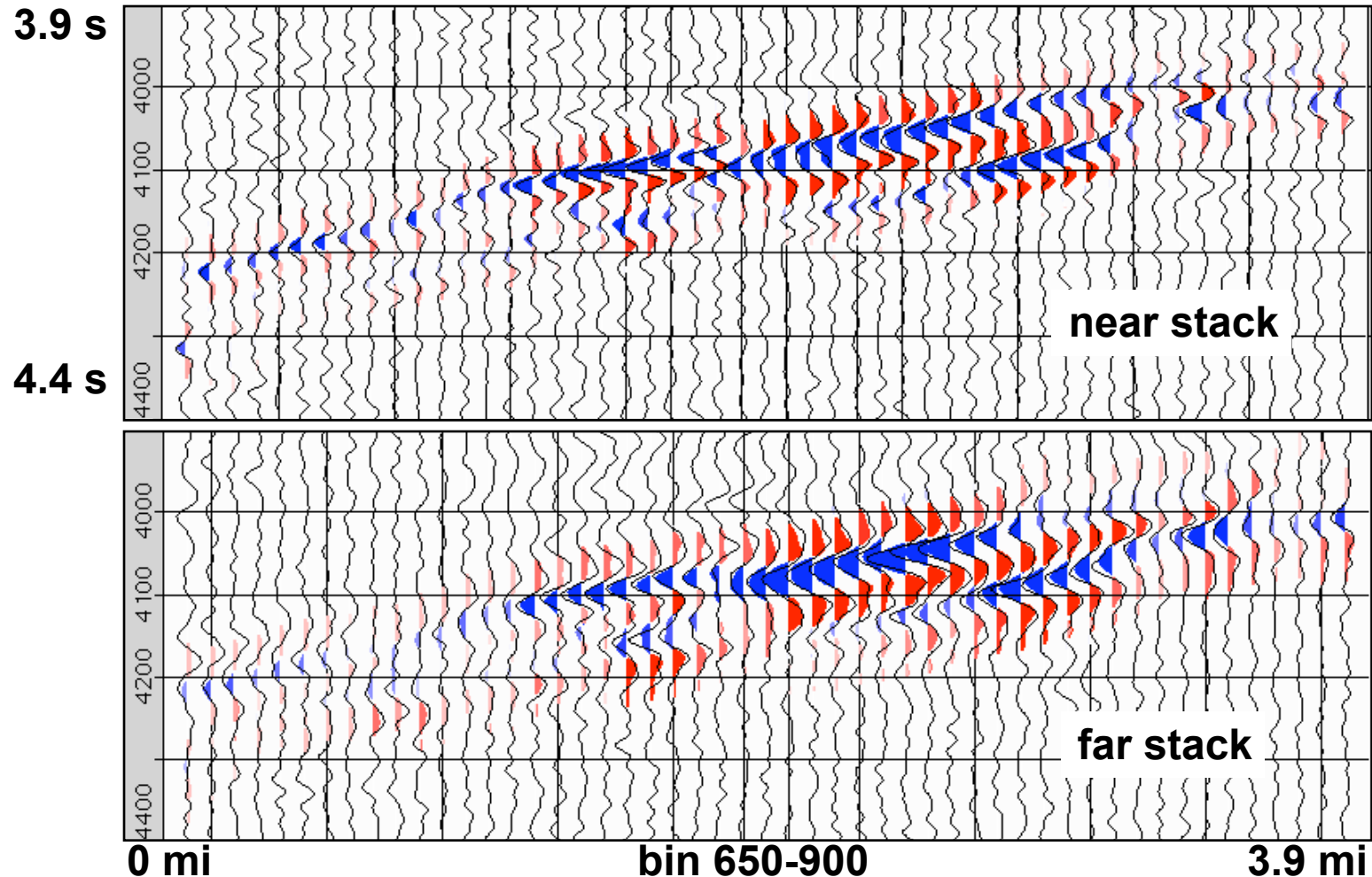


**time (ms)**

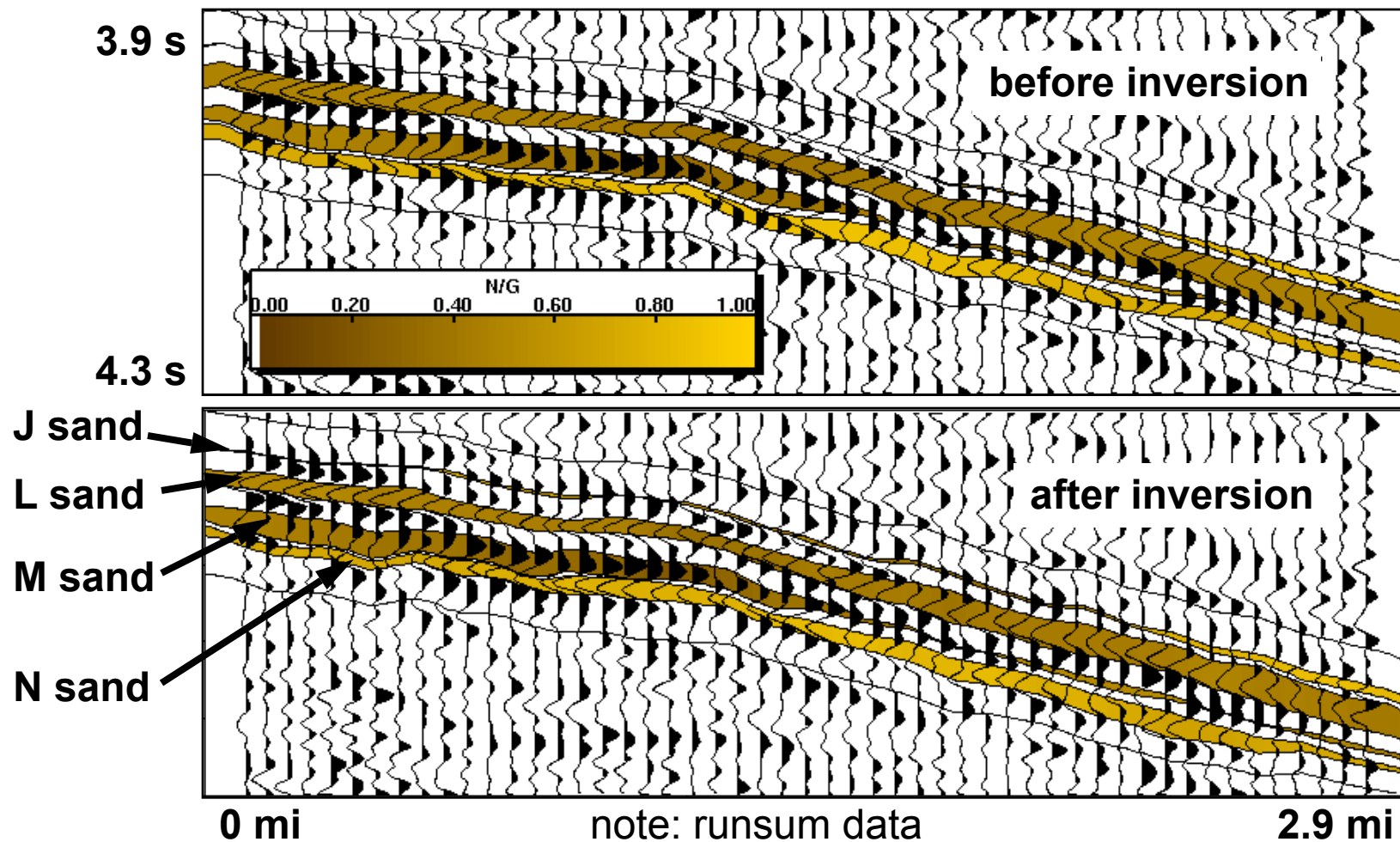
# Synthetic data after inversion (red-blue) compared to seismic runsum data (trk 8575)



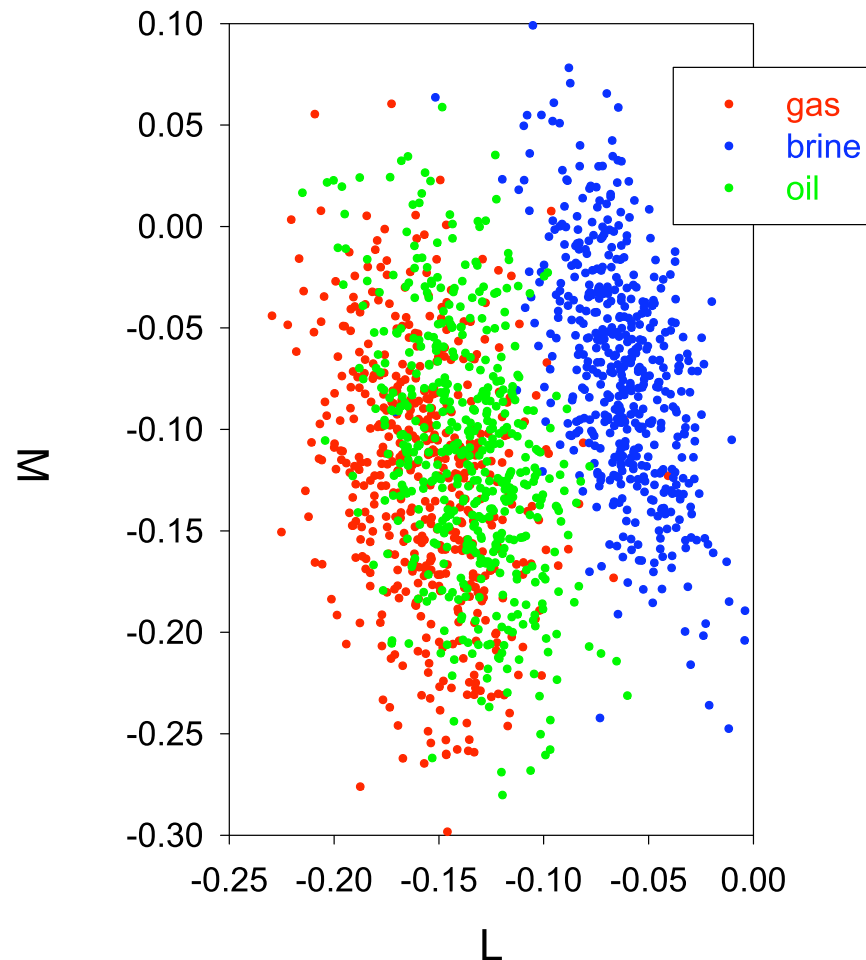
956-2ST2 ●



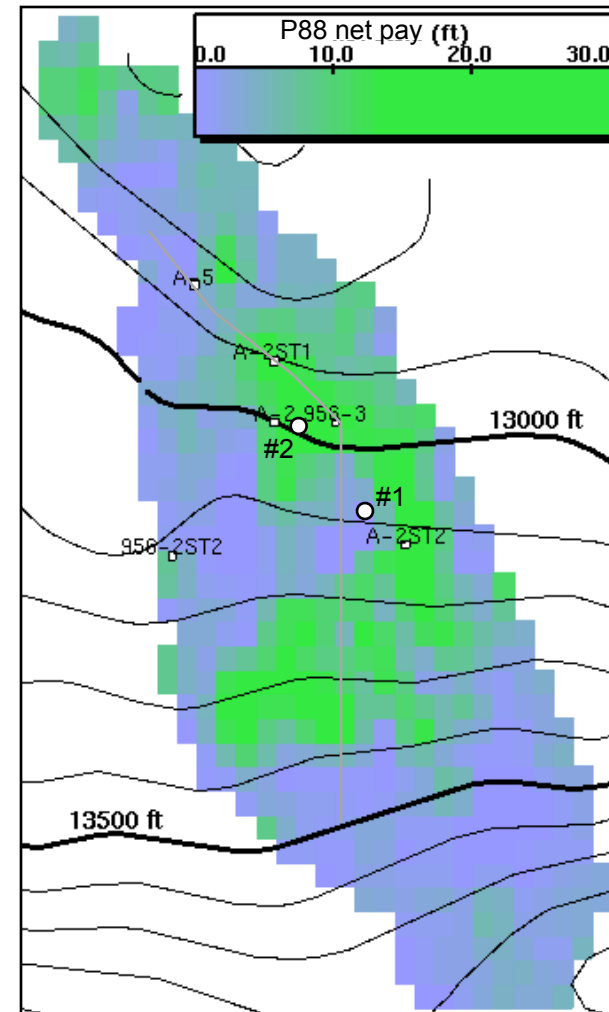
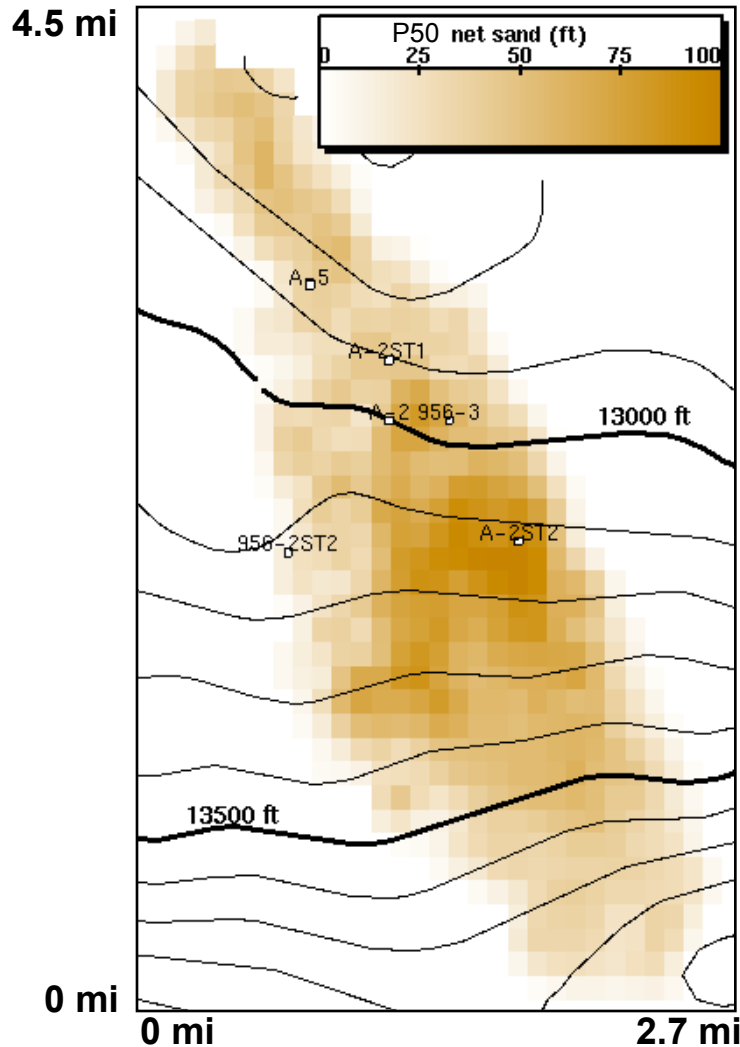
# PROMISE inversion updates P50 model



# Brine is distinct from pay but oil is similar to gas

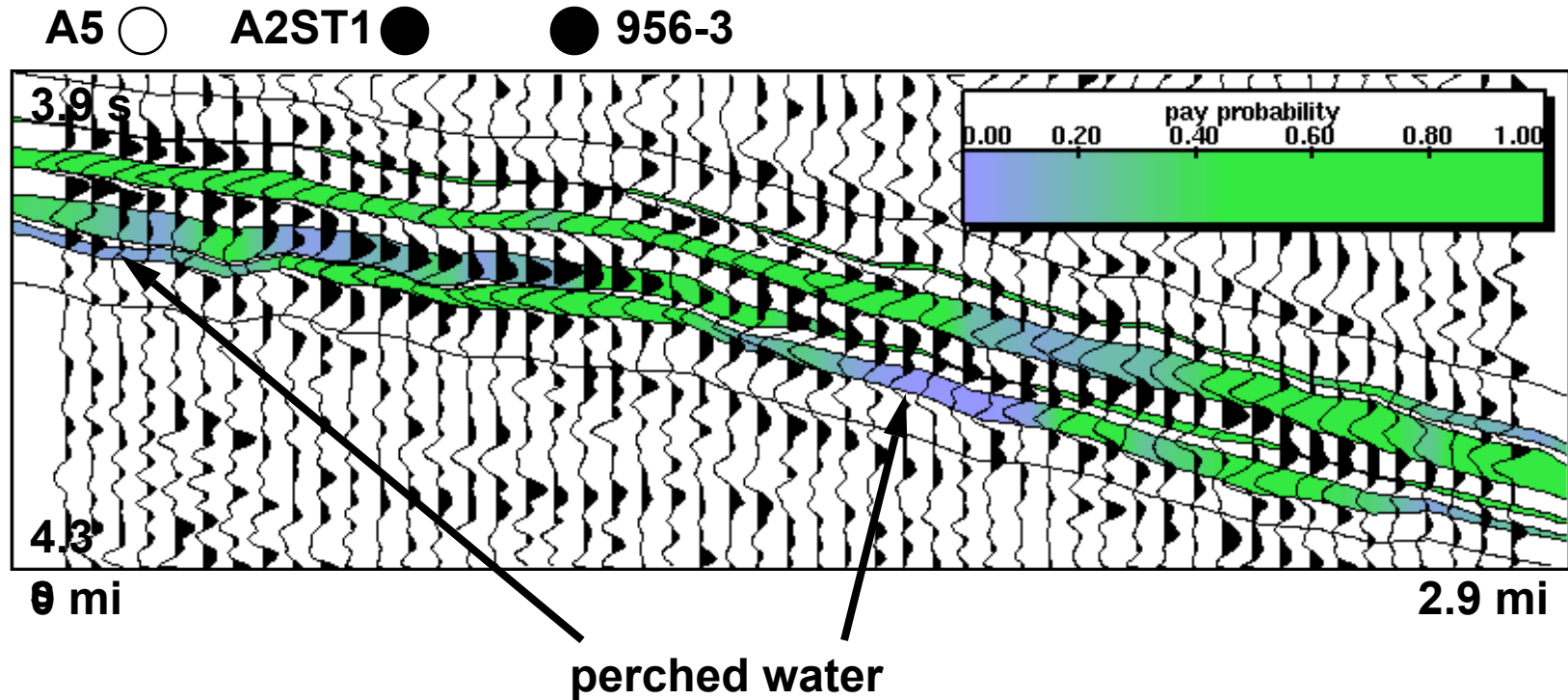


# Inversion results of N sand shows perched water levels



**net pay = thickness \* N/G \* porosity \* pay probability**

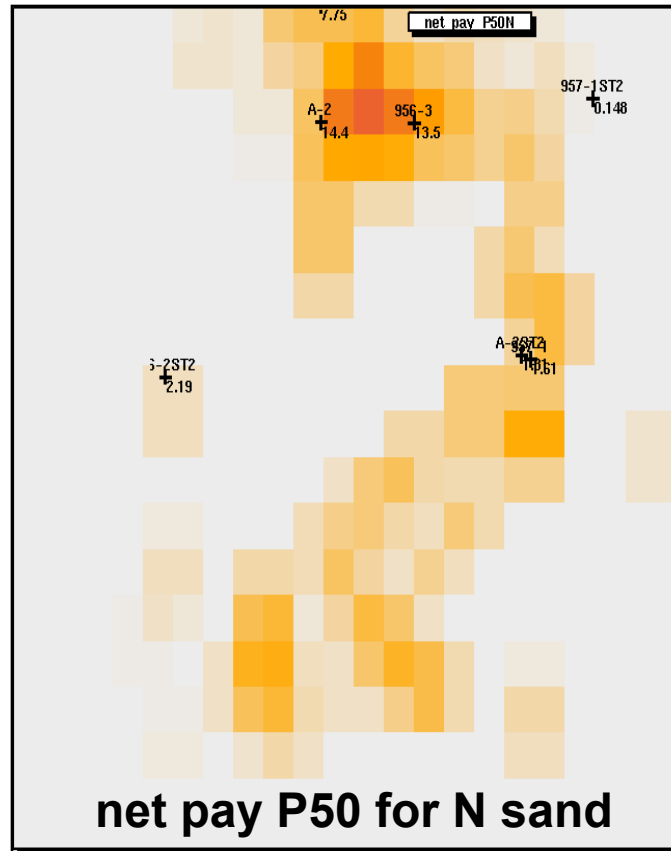
# Cross section showing perched water level in N-sand



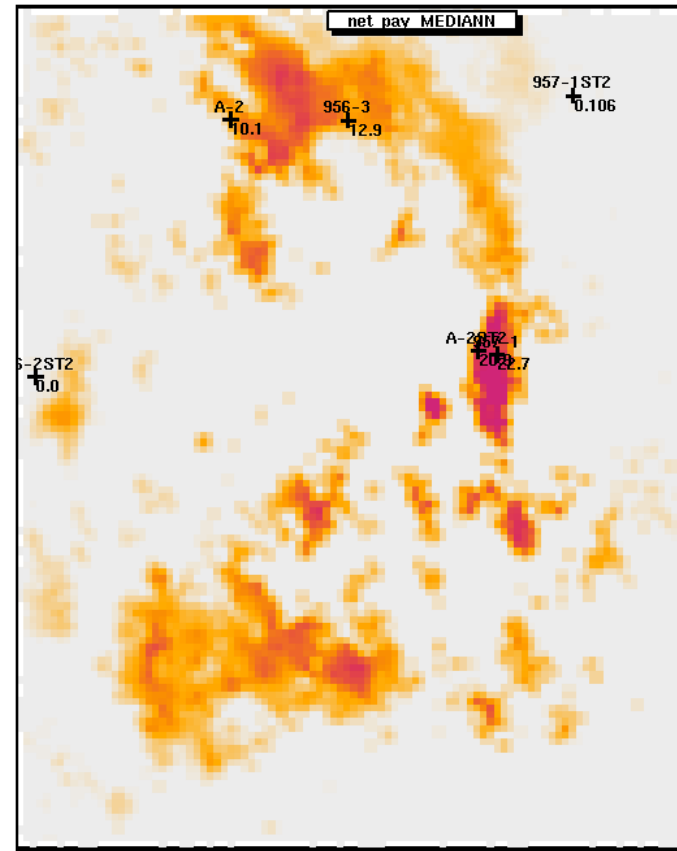
# What can be seen in N sand with higher resolution?



DepSim model resolution



seismic resolution (5x)



# Inversion is consistent with well information

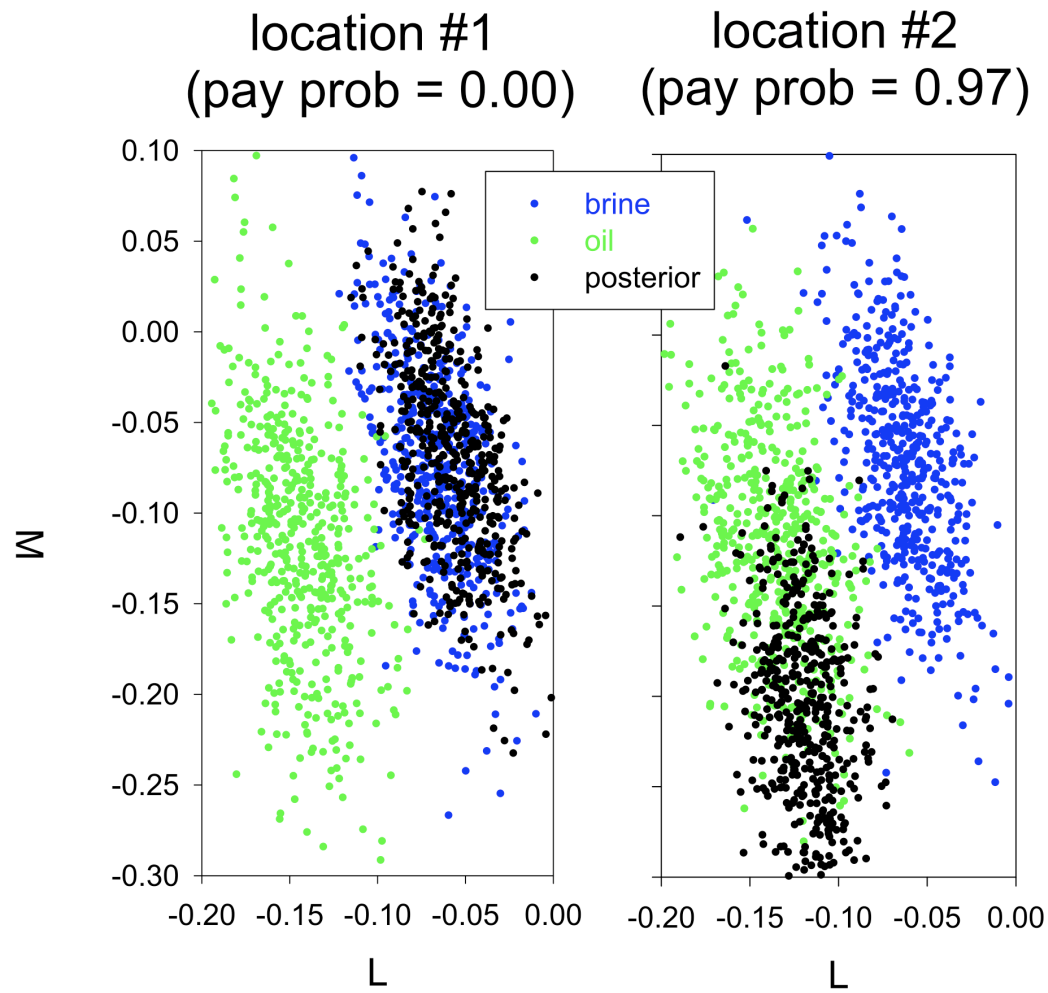


- **A5 wet**
- **A2 OWC**
- **A2ST1, 956-3, A2ST2, 956ST2 oil**
- **956-3 and A2ST2 in pressure communication**
- **42 MMrb connected to A2ST2 (13 MMrb first 2-3 months)**
- **3 barriers @ 200, 200 & 900 ft from A2ST2**
- **2 barriers @ 800 & 1600 ft (30 degree angle) from A2ST1 & 956-3**

| <b>pore volume<br/>(MMrb)</b> | <b>inversion with<br/>infinite<br/>correlation length</b> | <b>inversion with<br/>2000 ft correlation<br/>length</b> |
|-------------------------------|-----------------------------------------------------------|----------------------------------------------------------|
| P12                           | 15                                                        | 27                                                       |
| P50                           | 43                                                        | 43                                                       |
| P88                           | 121                                                       | 69                                                       |



# View of the inversion results in L-M space



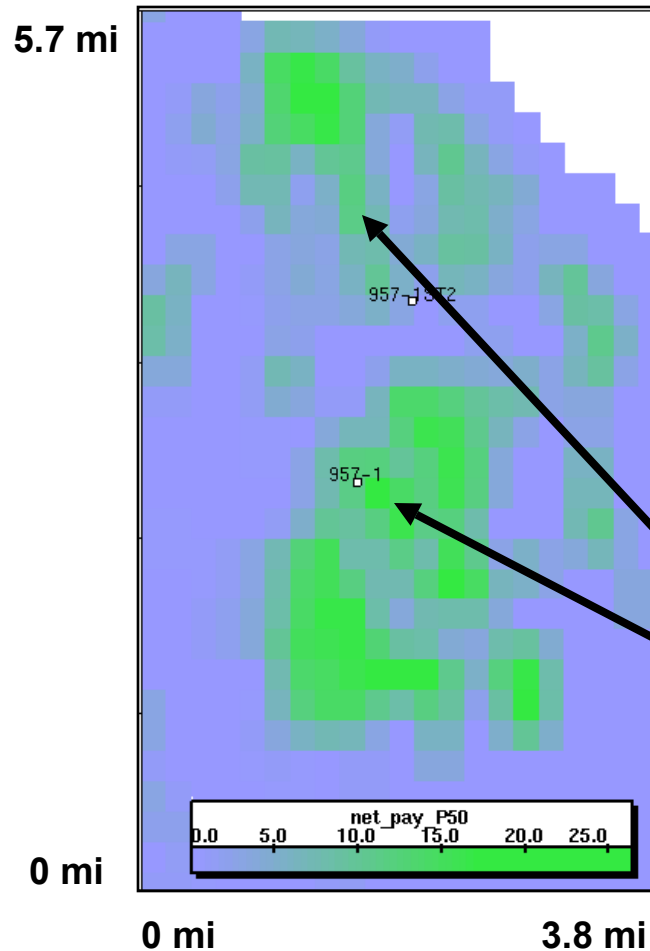
# Multiple stack inversion adds value at location #2 (oil in N sand)

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| fluid prediction | with AVO | without AVO |
|------------------|----------|-------------|
| oil              | 65%      | 41%         |
| gas              | 32%      | 38%         |
| residual gas     | 3%       | 3%          |
| brine            | 0%       | 18%         |

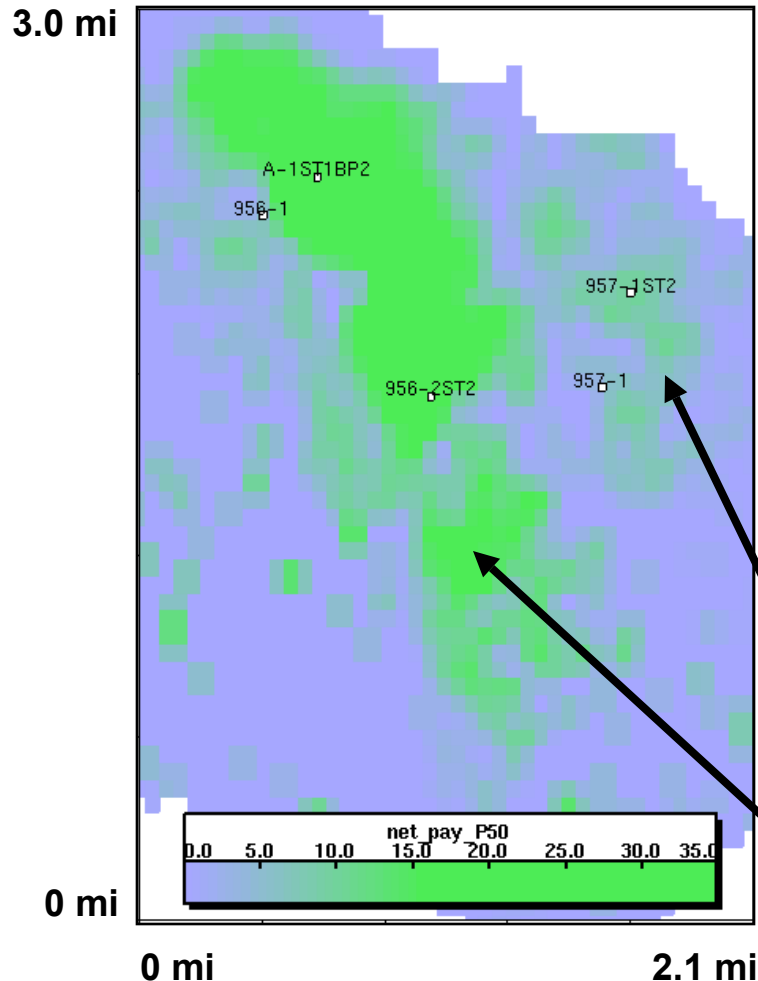
# Possible compartmentalization of M sand



- 957-1ST2 geochem outlier
- 957-1 pressure depleted by N sand production
- lower pod predicted volume 37,69,118 MMrb (P12,P50,P88,w/ 4000 ft correlation) -- booked volume 82 MMrb

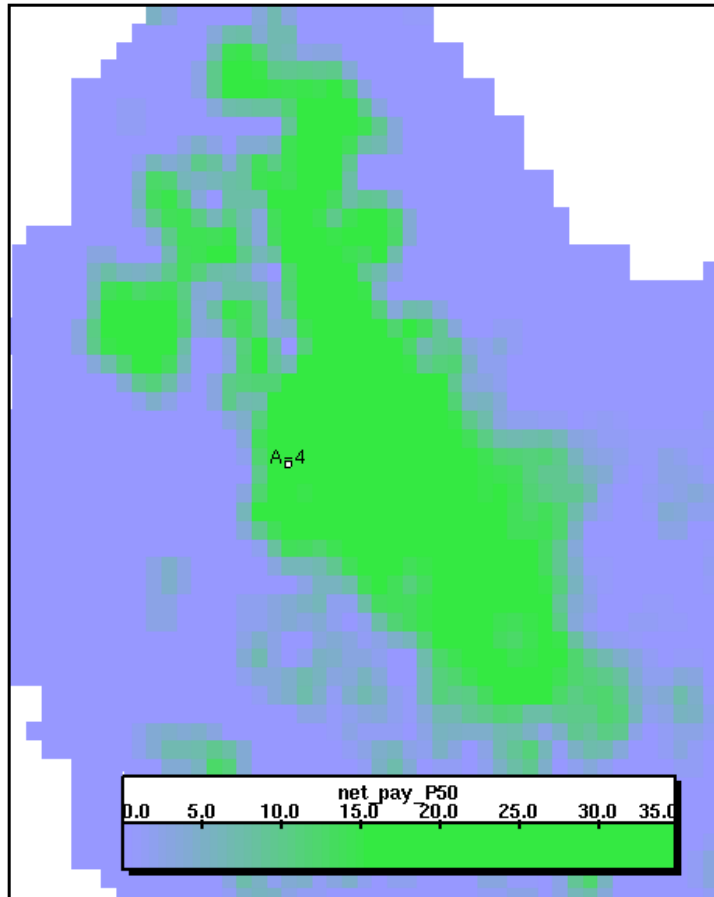
two compartments ??

# Possible bypassed pay in L sand



- 957-1 & 956-2ST2 pressure profiles do no line up
  - 956-2ST2 gas over water with shale in between
  - 956-1 gas over water with shale in between
  - 957-1 OWC
  - predicted volume of upper lobes 266,301,334 MMrb (P12,P50,P88,w/ 3000 ft correlation) -- booked volume 191 MMrb -- mass balance >260 MMrb
- splay or breach ??
- by-passed pay ??, 42,93,155 MMbe

# OWC is seen in J sand

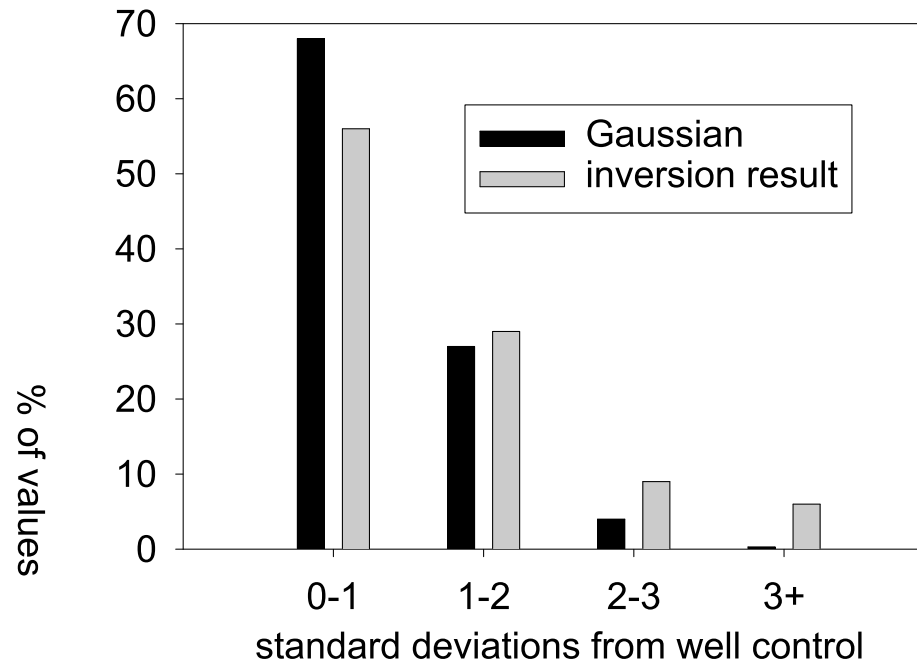


- A-4 OWC
- predicted volume 368,422,470 MMrb (P12,P50,P88,w/ 8000 ft correlation, increased > 2 sigma by inversion) -- booked volume 601 MMrb

# Inverted model compared to well control



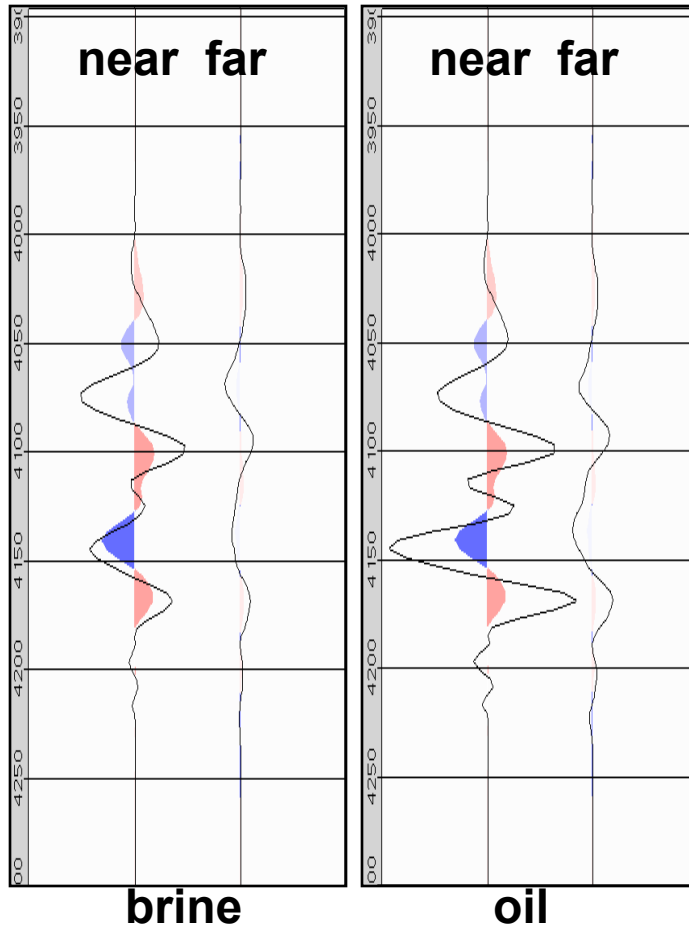
- 41 wells
- thickness, N/G and fluid for each sand penetration
- 146 values to match
- large number of 3+ in J sand (prior not good)



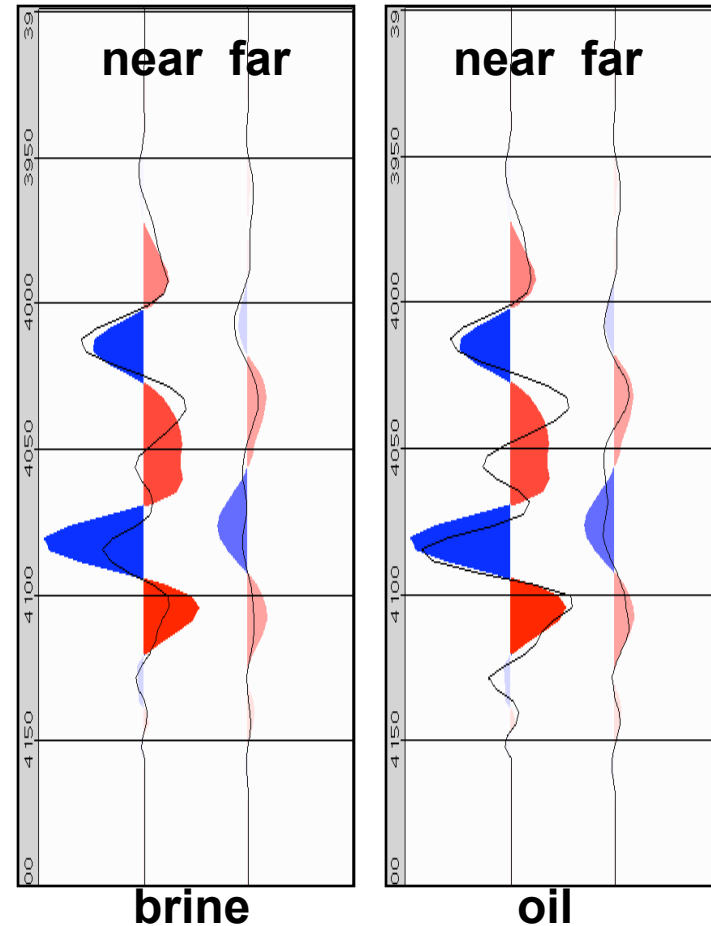
# Synthetic before inversion for critical locations compared to result after inversion (red-blue)



location #1 (pay prob = 0.00)



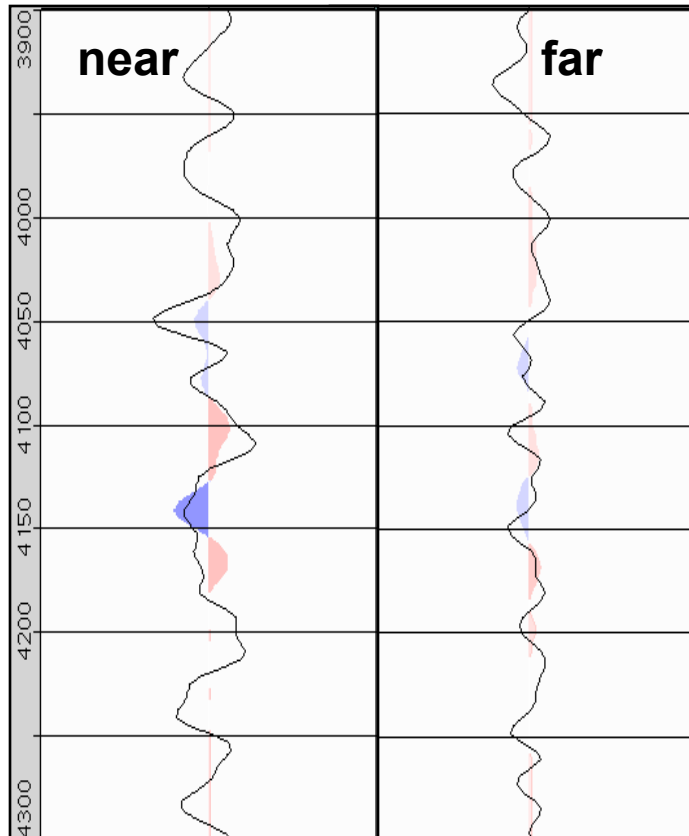
location #2 (pay prob = 0.97)



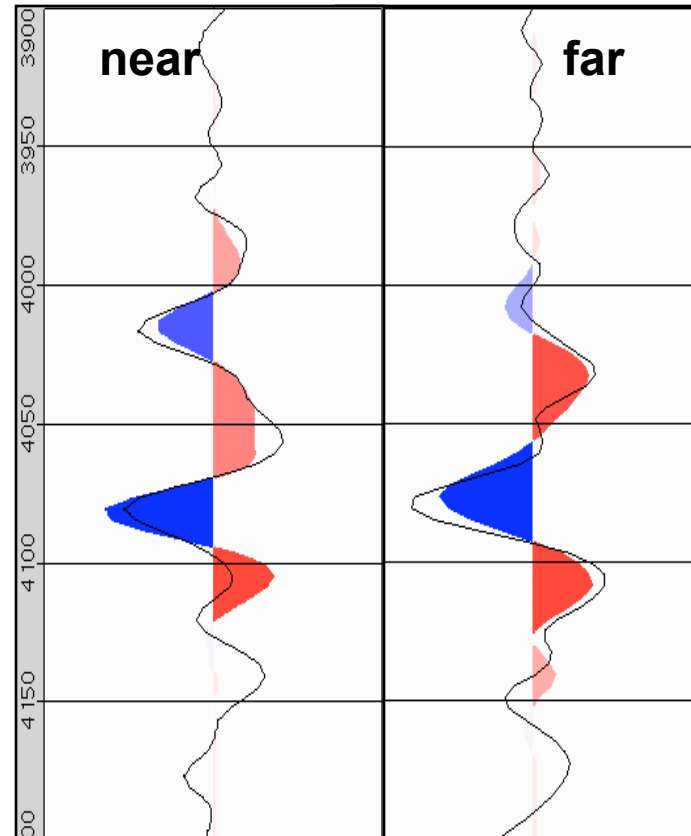
# A closer look at match of synthetic (red-blue) to seismic at critical locations



location #1 (pay prob = 0.00)



location #2 (pay prob = 0.97)



note: +6dB gain on far