



Probabilistic AVO inversion on Gannet E

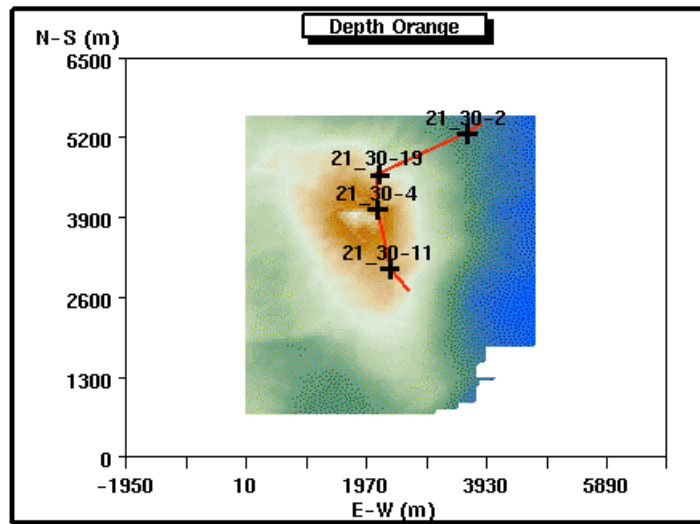
Gerard Bodewitz

Shell Expro

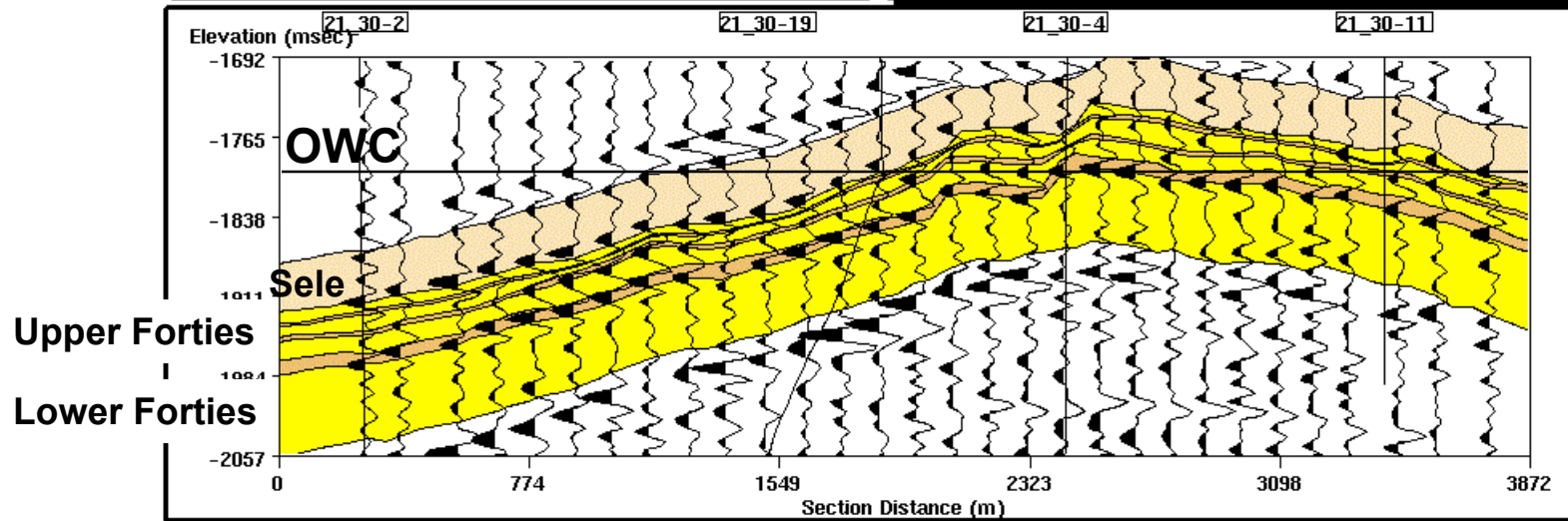
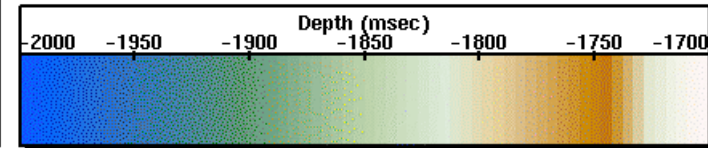
Michael Glinsky, Conrad McCarthy and Eldon Sims

Shell E&P Technology Co.

Structure of Gannet E



Note: seismic is near stack, rfc, SEG polarity



How petrophysical trends were derived



- **end member sand vp and density found by histogramming intervals where $X_{NETPOR} > 0.05$**
 - done separately for oil and wet sands, oil sand was consistent with Gassman substituted wet sand
 - four wells (21-30-2, 21-30-4, 21-30-11, 21-30-19)
 - swell vp-porosity slope
- **bounding shale vp and density found by histogramming Sele**
 - four wells
 - swell vp-density slope
- **mixing shale vp and density found by histogramming Middle Forties Shale where it was deemed to be a good clean shale $X_{NETPOR} = 0$**
 - four wells
 - swell vp-density slope
- **wet end member sand vp-vs relationship found by regressing clean wet sands at GANNET A-1 well**
- **vp-vs for shales from swell**

Details of petrophysical trends



clean wet sand:

$$vp(\text{in ft/s}) = 9560 \pm 250$$

$$vs(\text{in ft/s}) = 0.8940 * vp - 3692 \pm 221$$

$$\text{porosity} = -2.4667e-5 * vp + 0.5243 \pm 0.018$$

mixing mudrock:

$$vp = 8114 \pm 300$$

$$vs = 0.8012 * vp - 3500 \pm 220$$

$$\text{density}(\text{in gm/cc}) = 0.10885 * vp ^ 0.33501 \pm 0.05$$

Sele (shale):

$$vp = 7300 \pm 250$$

$$vs = 0.8012 * vp - 3500 \pm 220$$

$$\text{density}(\text{in gm/cc}) = 0.081749 * vp ^ 0.36112 \pm 0.10$$

oil:

$$vp = 3983 \text{ ft/s}$$

$$\text{density} = 0.856 \text{ gm/cc}$$

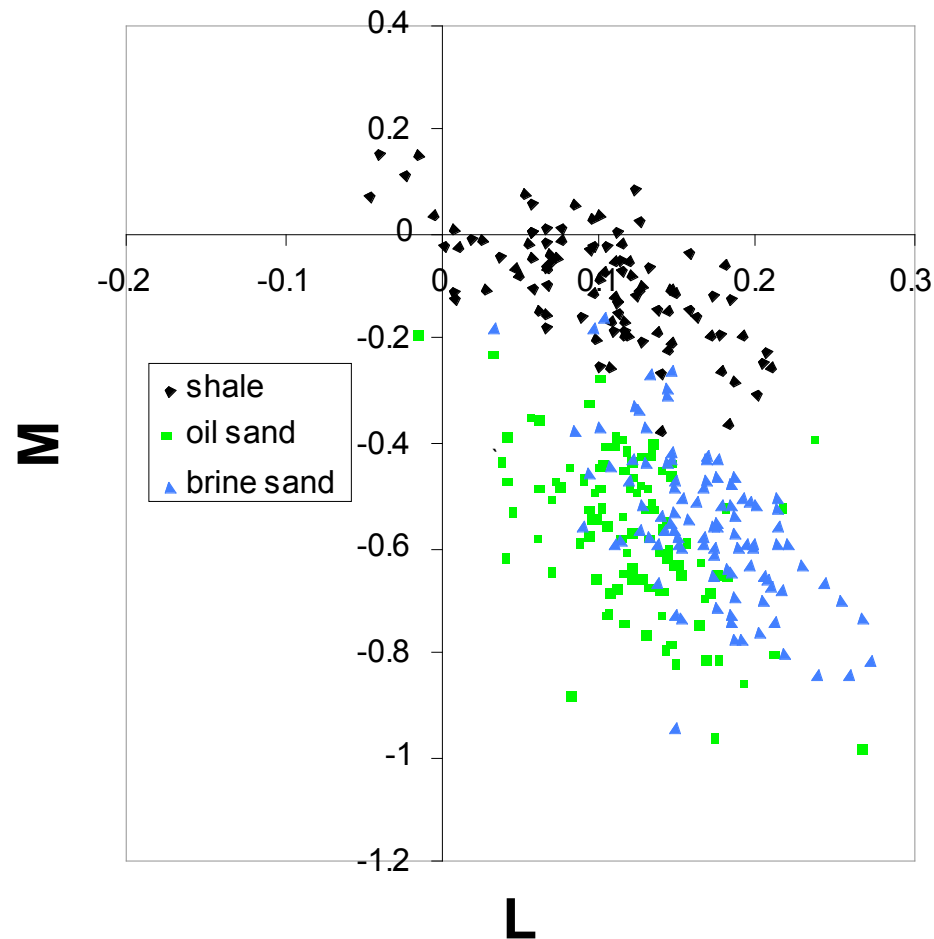
$$\text{saturation} = 80\%$$

brine:

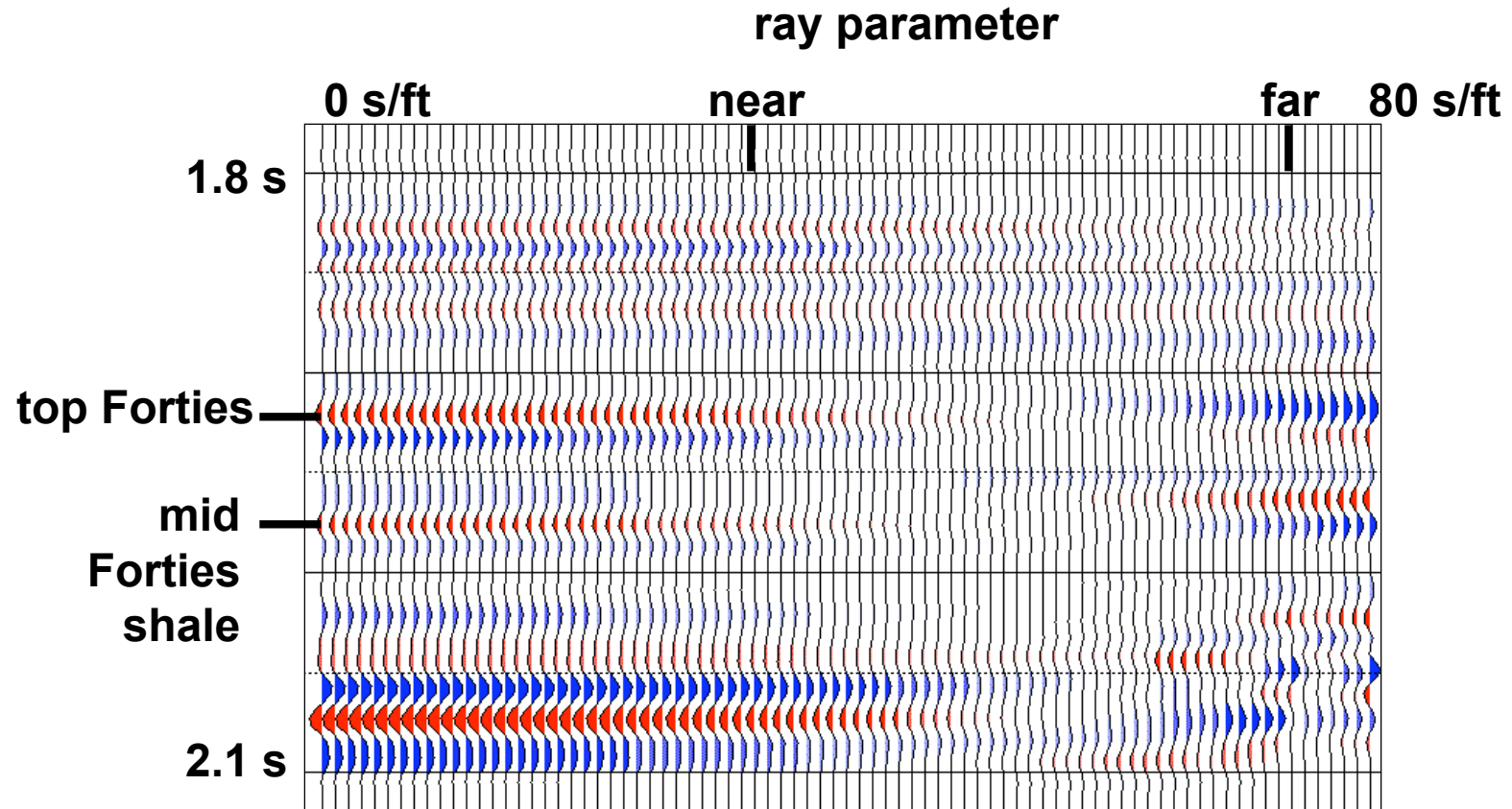
$$vp = 5361 \text{ ft/s}$$

$$\text{density} = 1.026 \text{ gm/cc}$$

Separation in LM space

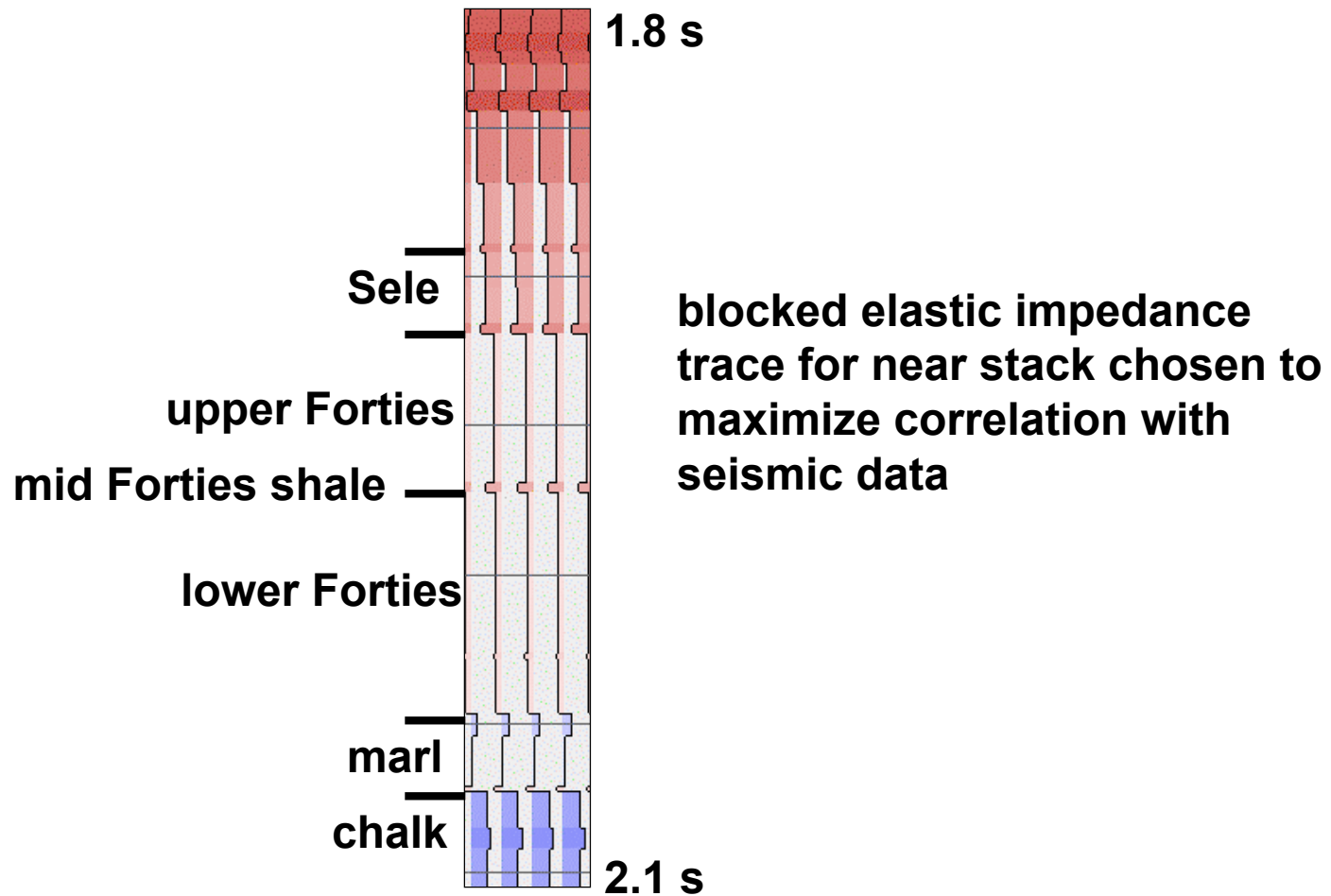


Synthetic AVO response at well 20-31-2

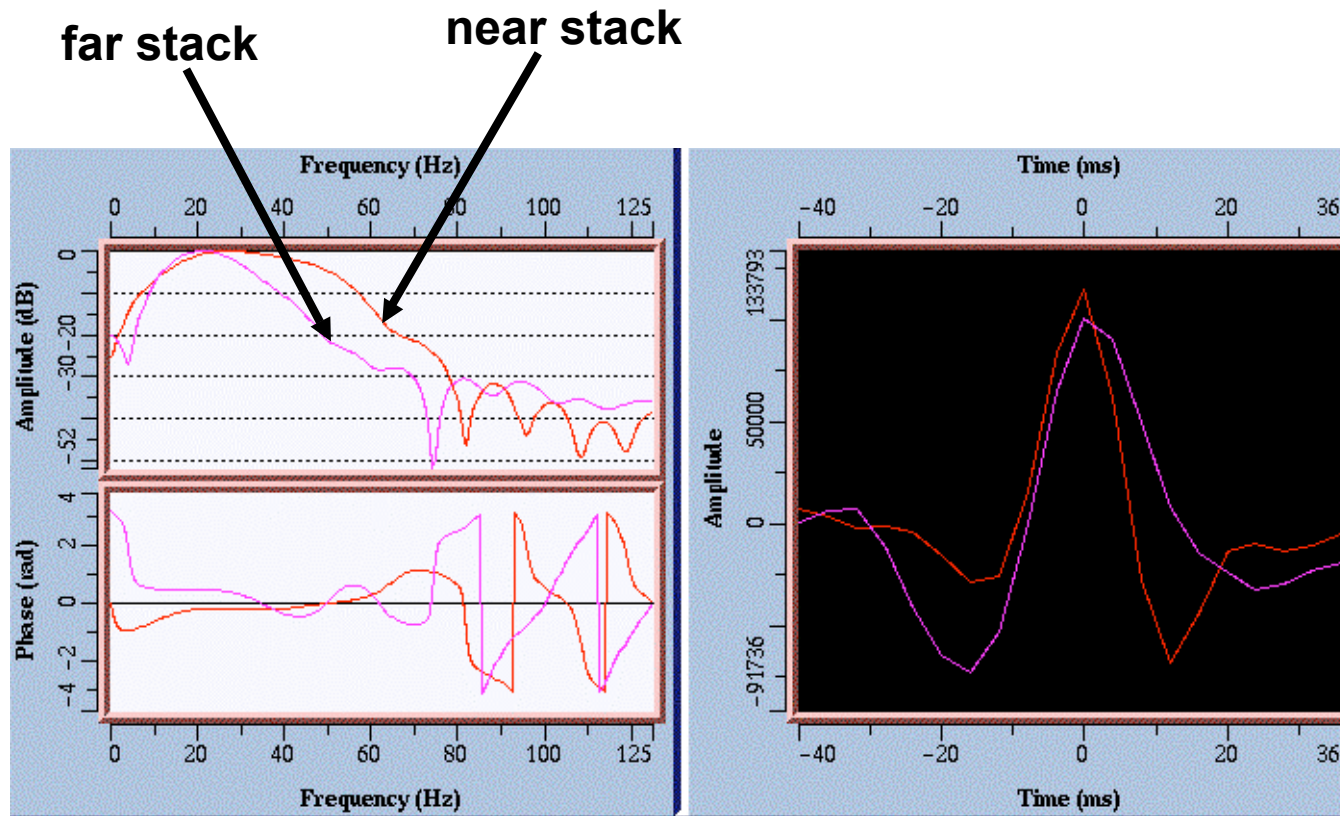


note: small angle approximation

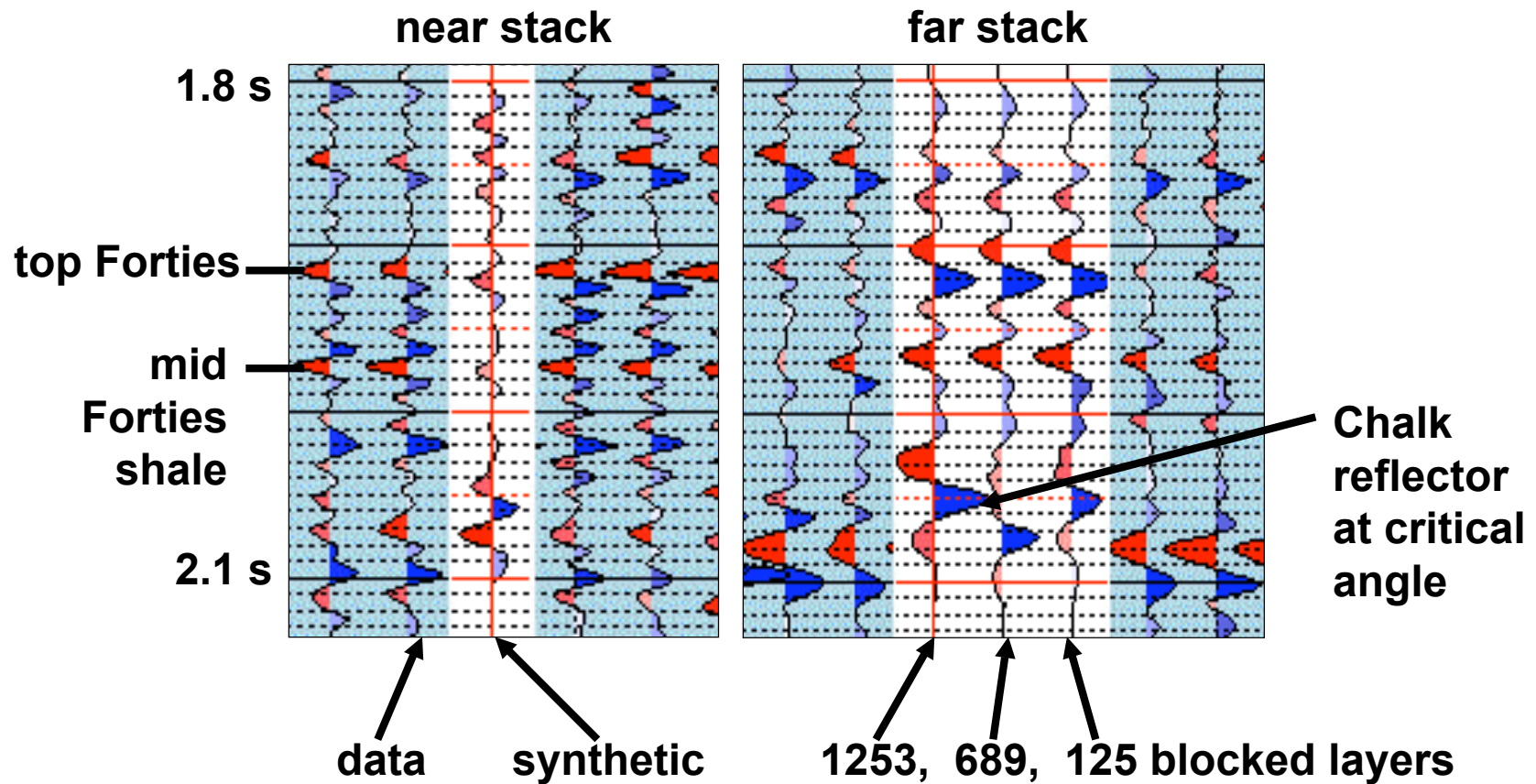
Natural Blocking of well 21-30-2



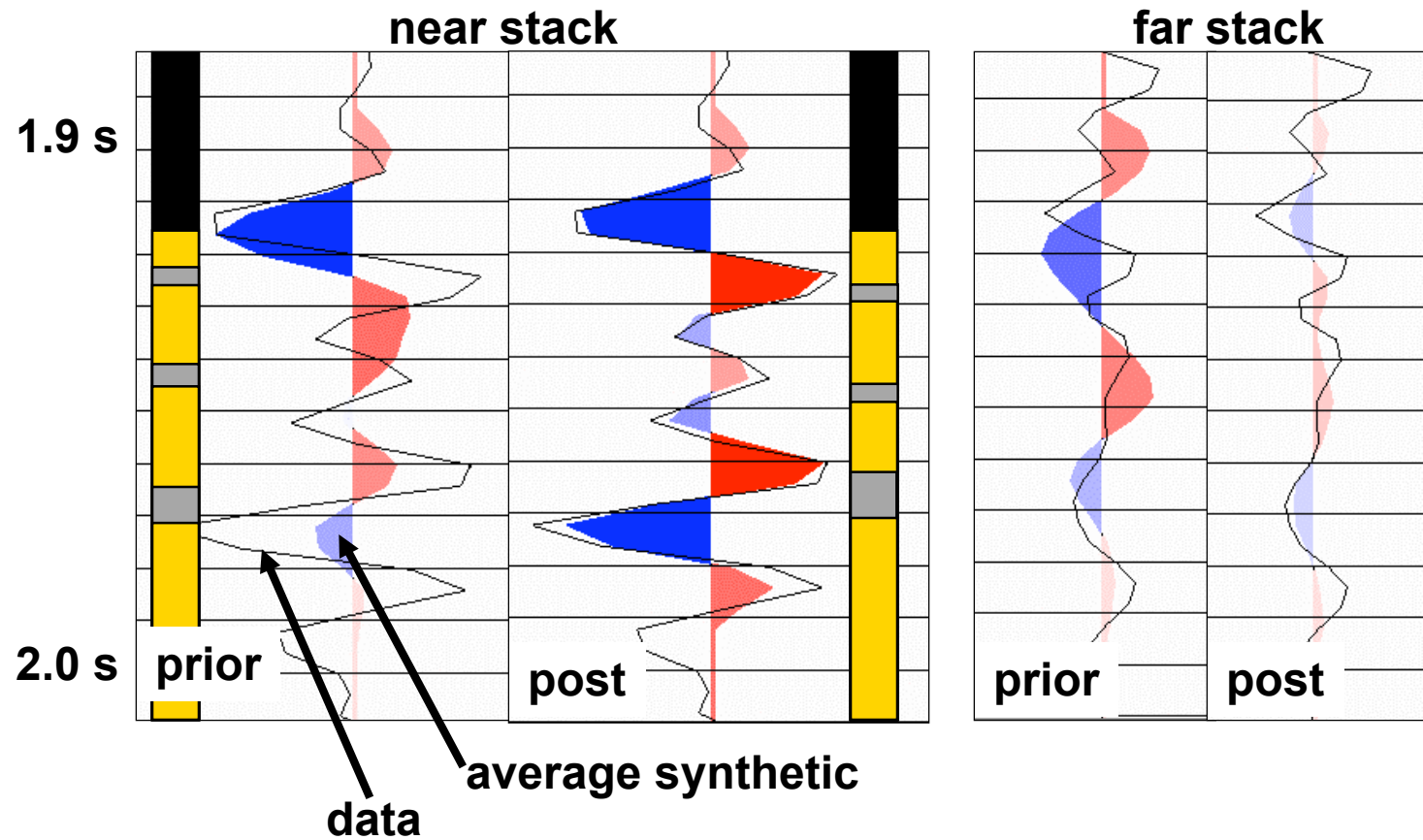
Wavelets (derived at well 21-30-2)



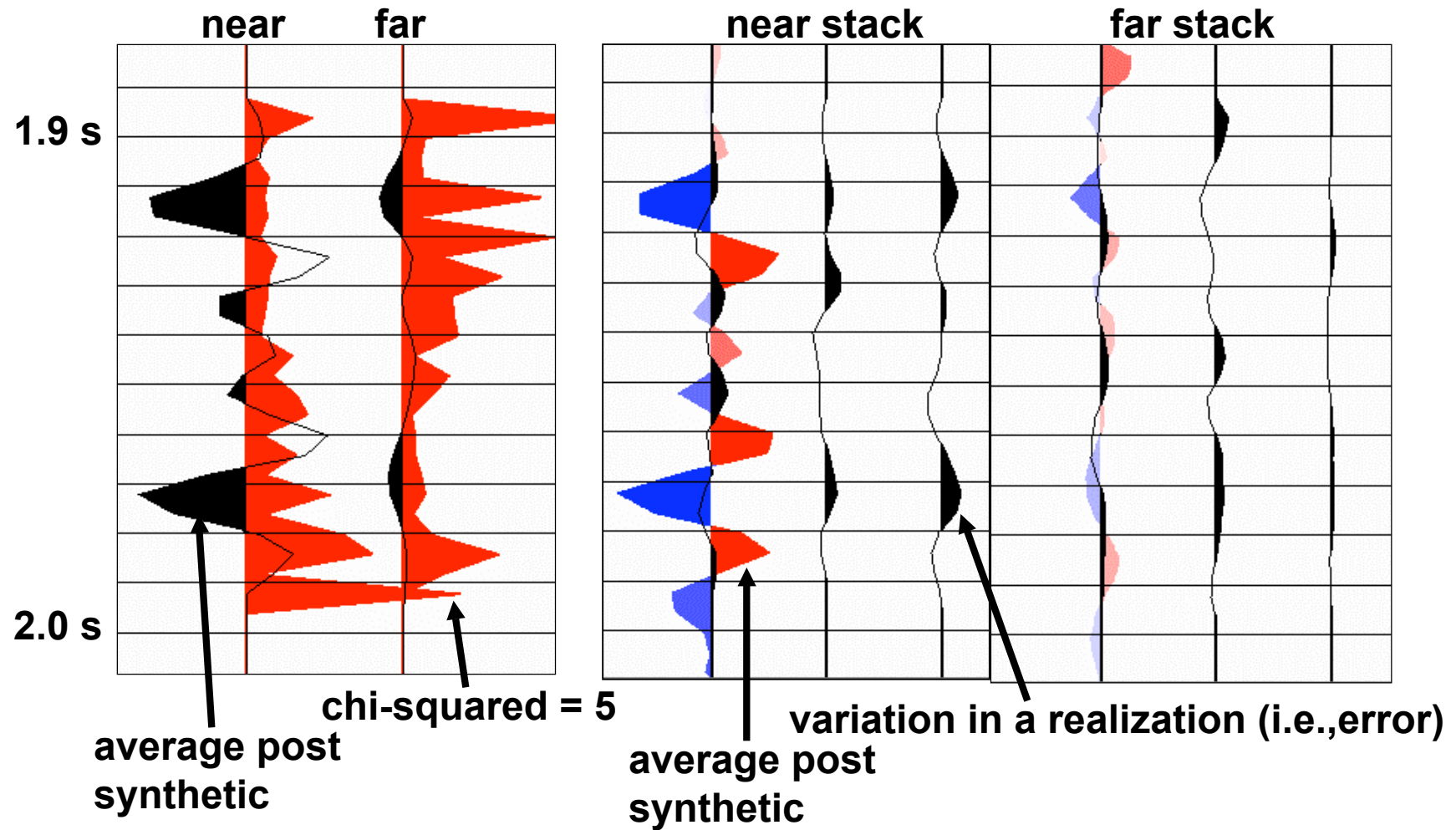
Tie to seismic at well 21-30-2



Inversion at well 21-30-2



Error and noise level at well 21-30-2



Summary of inversion at well 21-30-2



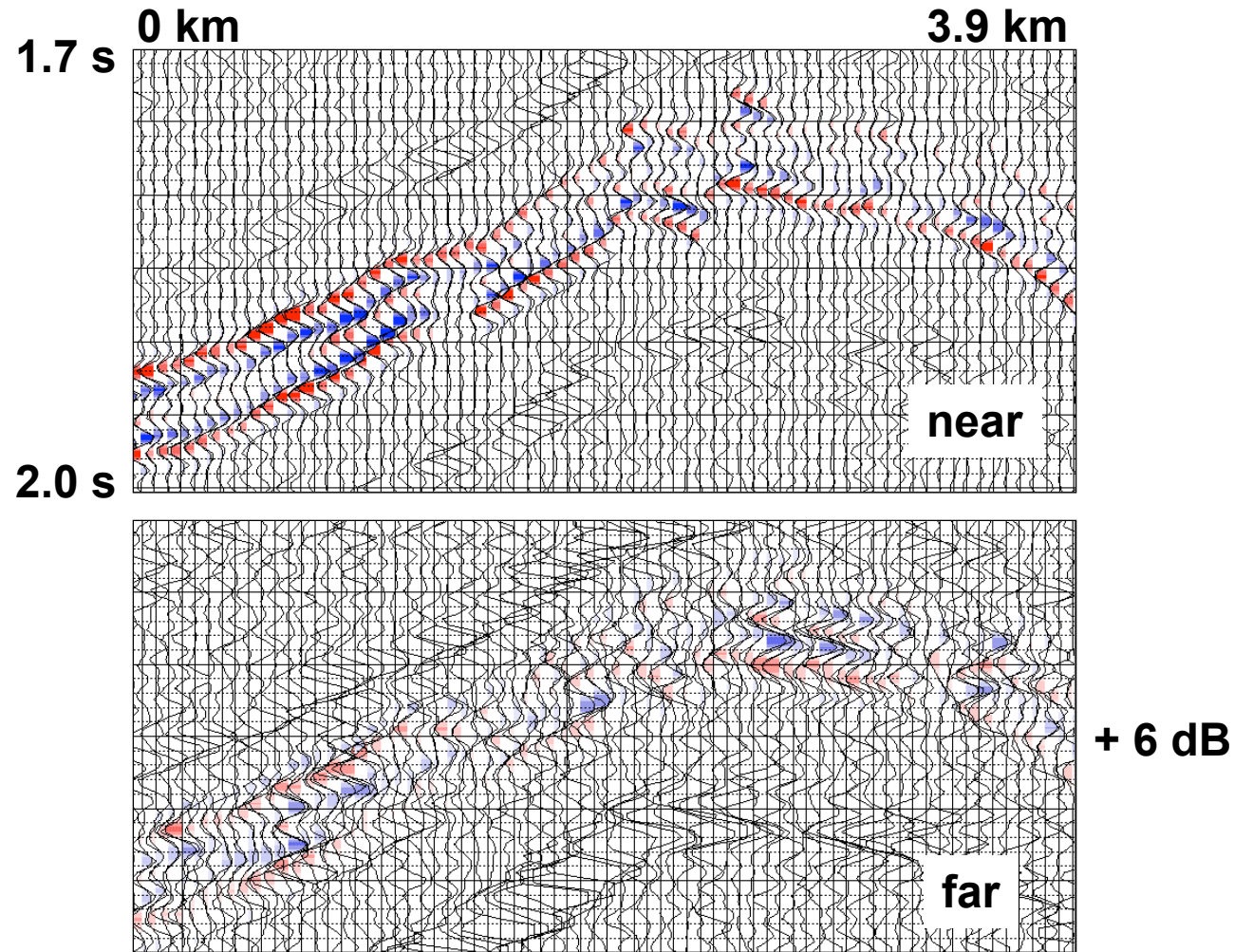
- **top Forties and mid Forties shale arrival time standard deviation decreased from 3 ms to 1 ms**
- **L&M standard deviation of top Forties and mid Forties reflectors decreased by a factor of 2**
- **standard deviation of upper Forties thickness decreased by a factor of 3**
- **standard deviation of upper Forties net sand decreased by 25%**
- **standard deviation of OIIP decreased by a factor of 5**
- **all P50 values are within 2 standard deviations of actual values**

Some details of the inversions

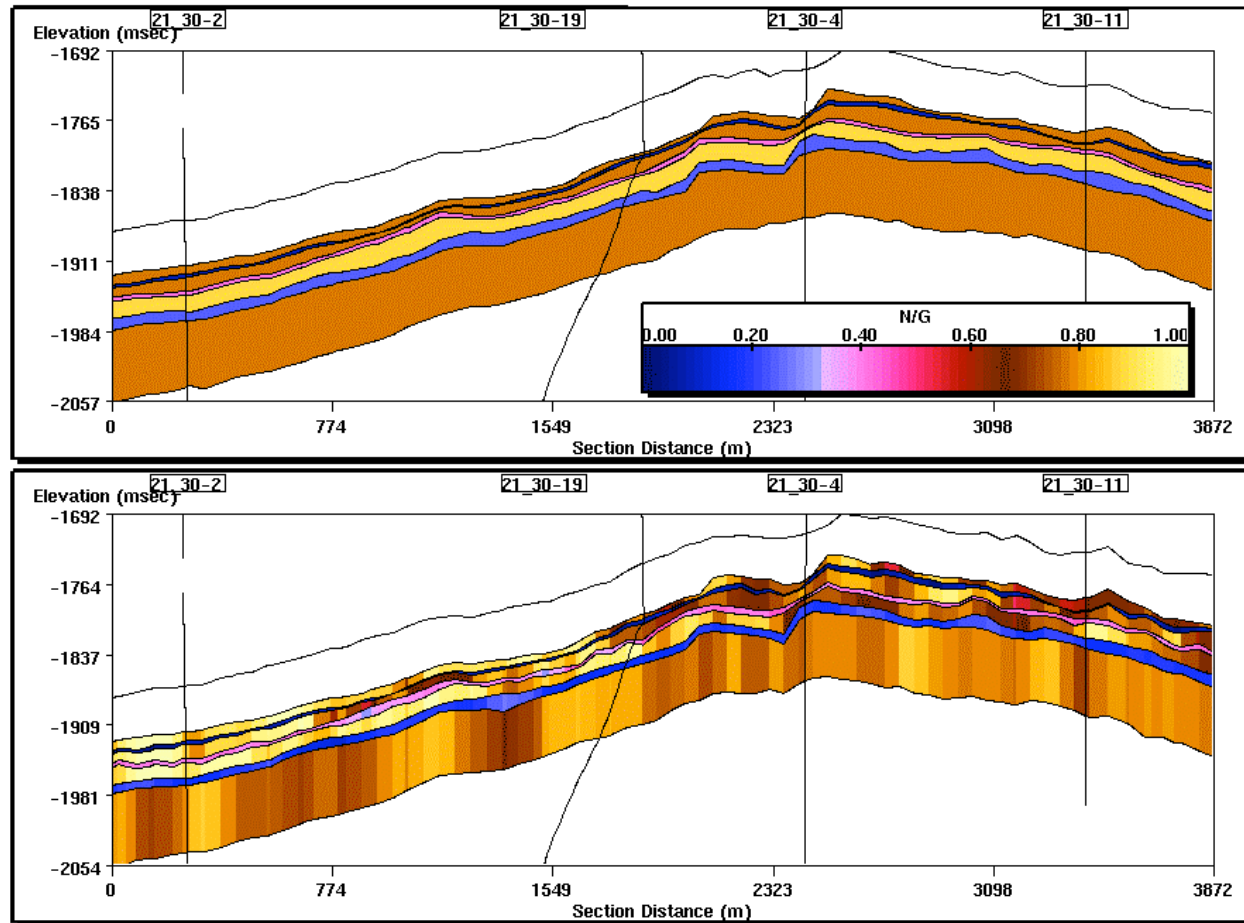


- **V3 (not krieged to well control)**
 - N/G well averages, standard deviation is that of well values (25% for upper Forties sands, 10% otherwise)
 - thickness convergent geometry (80/20 sand/shale ratio), standard deviation one third thickness (250 m half width smoother)
 - pay probability 2% below flat spot, 98% above (250 m half width smoother)
 - structure built from maps for top Forties, top Pink sand, top Blue sand, top mid Forties shale -- constrained within 4 ms
- **V4 (krieged to well control) same as V3 except:**
 - N/G fitted to well values (error krieging from V3 N/G with updates only within range), standard deviation varied from 2% at wells to that of V3 away from wells (range 3000 m to NW, 1000 m to NE)
 - thicknesses fitted to vertical well values, standard deviation varied from 1 ft at wells to 20% of thickness away from wells (20% determined by the average amount that values were changed at the wells by the krieging) (range 1500 m to NW, 500 m to NE)

Comparison of synthetics after inversion (red-blue) to seismic data (black lines)



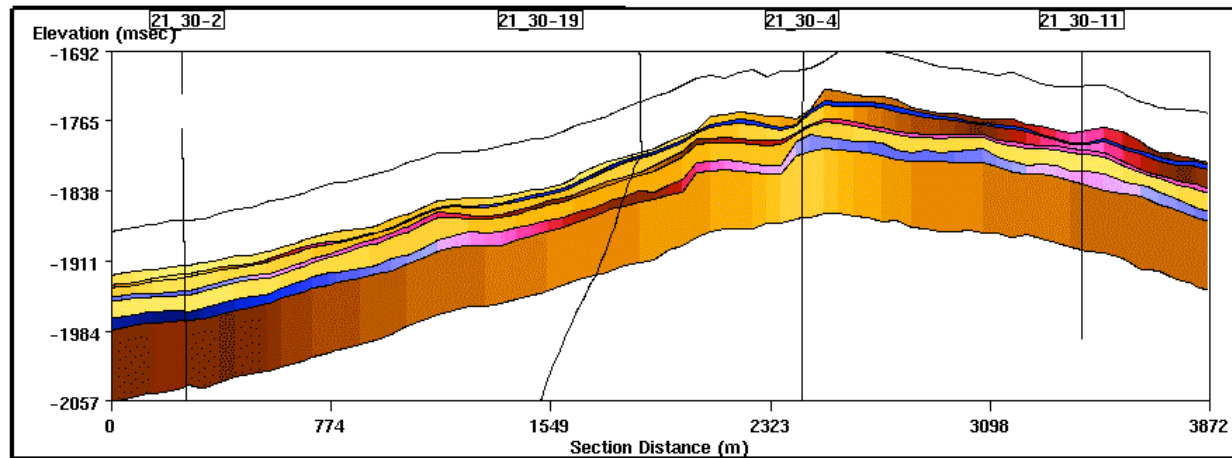
Results of inversion V3 without krieging thicknesses and N/G to well control



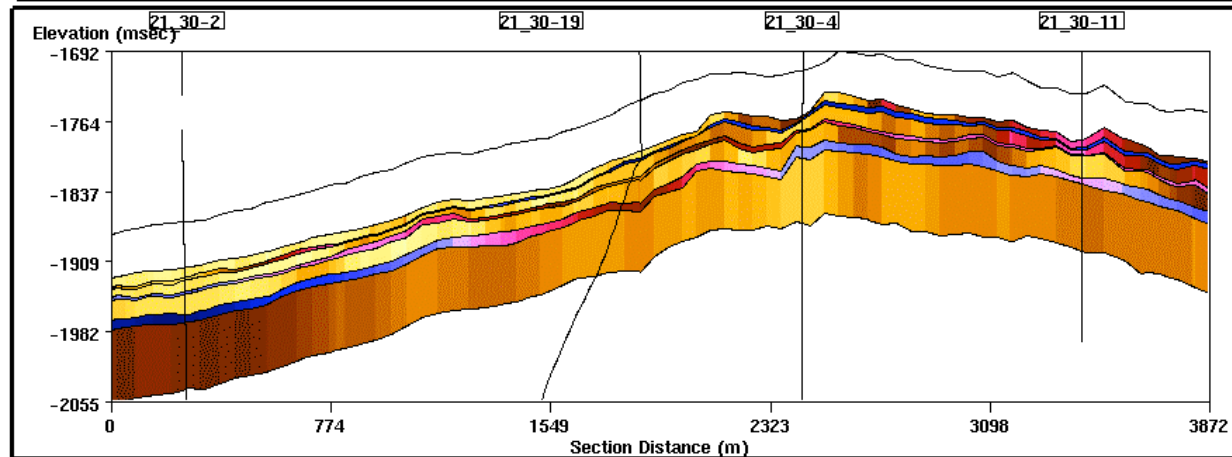
prior

post

Results of inversion V4, krieging thicknesses and N/G to well control



prior

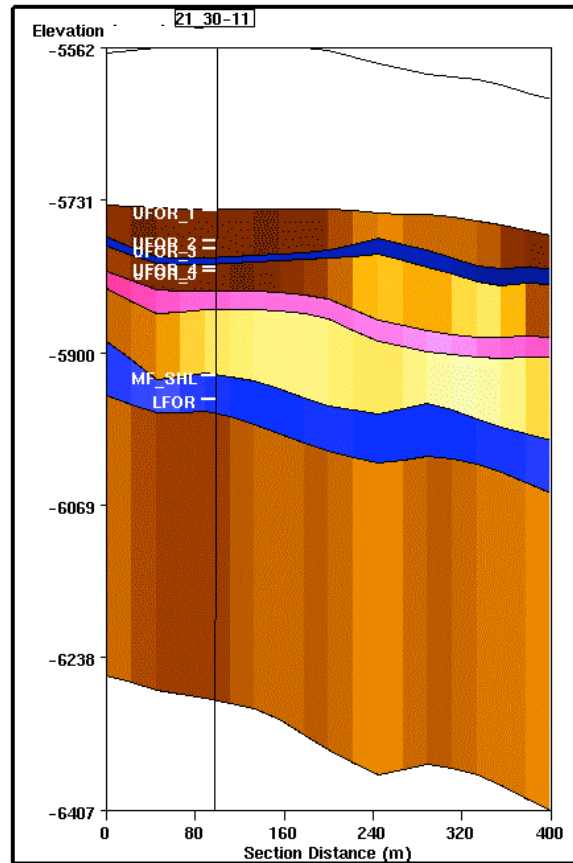


post

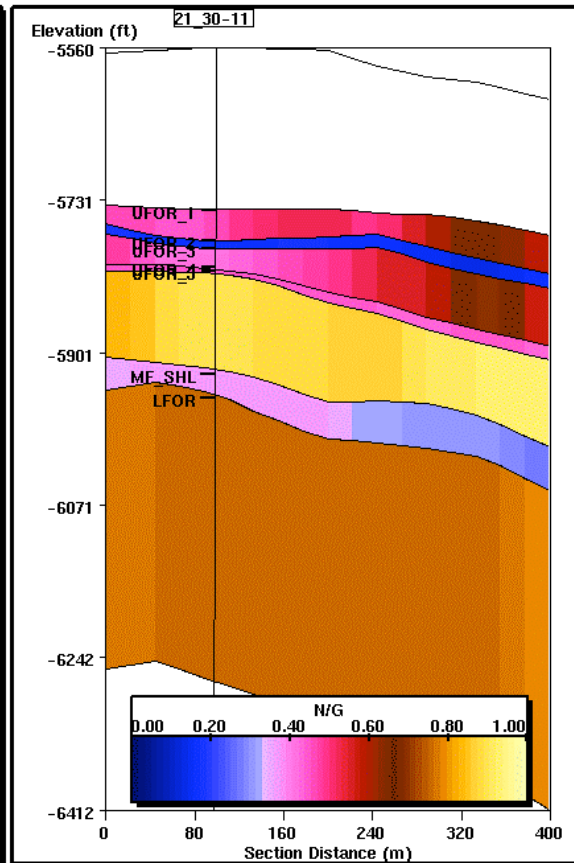
Results of inversion tie wells when the prior is fitted to well control



not fitted (V3)



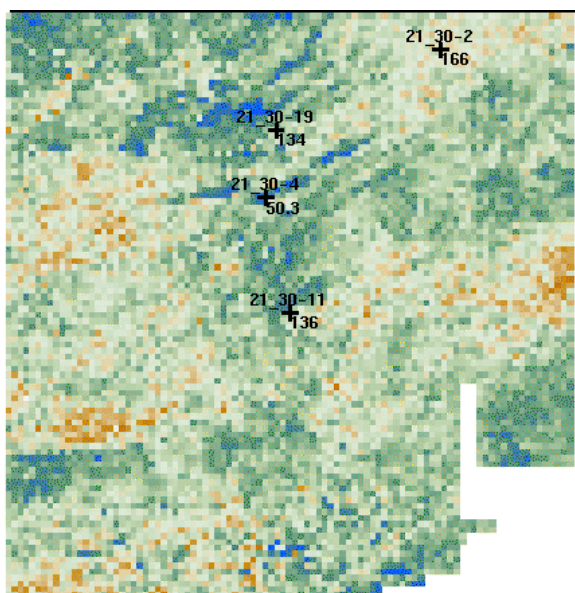
fitted (V4)



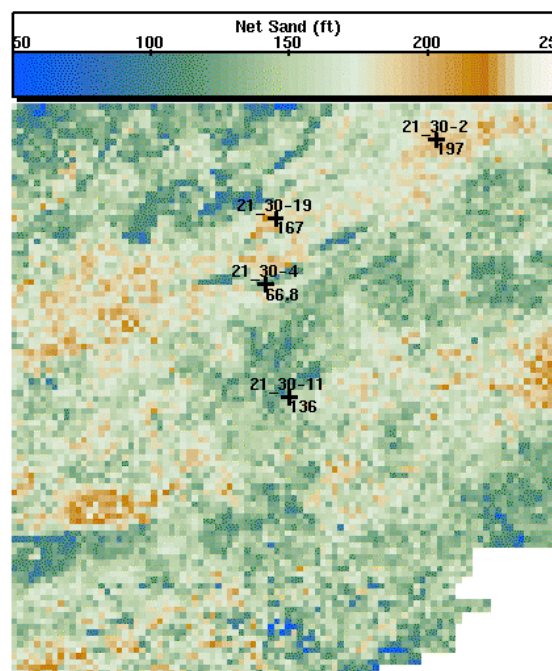
Difference in net sand map when well control is used



not fitted (V3)



fitted (V4)



error in net sand decreased from 17% to 10% by inversion V3

Inversion and well control improves the estimate of OIIP

