Waveform tomography for areas with complex near surface

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CREWES

Motivation

- Waveform tomography has been mainly used for complex models at depth, and mild near surface environments.

- We apply it to a complex near surface environment.

Outline

- Theory
- Complex near surface
  - Saudi Aramco model
- Shingling
- Conclusion

Theory

$$\nabla\left(\frac{1}{\rho(x,z)}\nabla P(x,z,\omega)\right)+\frac{\omega^2}{K(x,z)}P(x,z,\omega)=S(x,z,\omega)$$

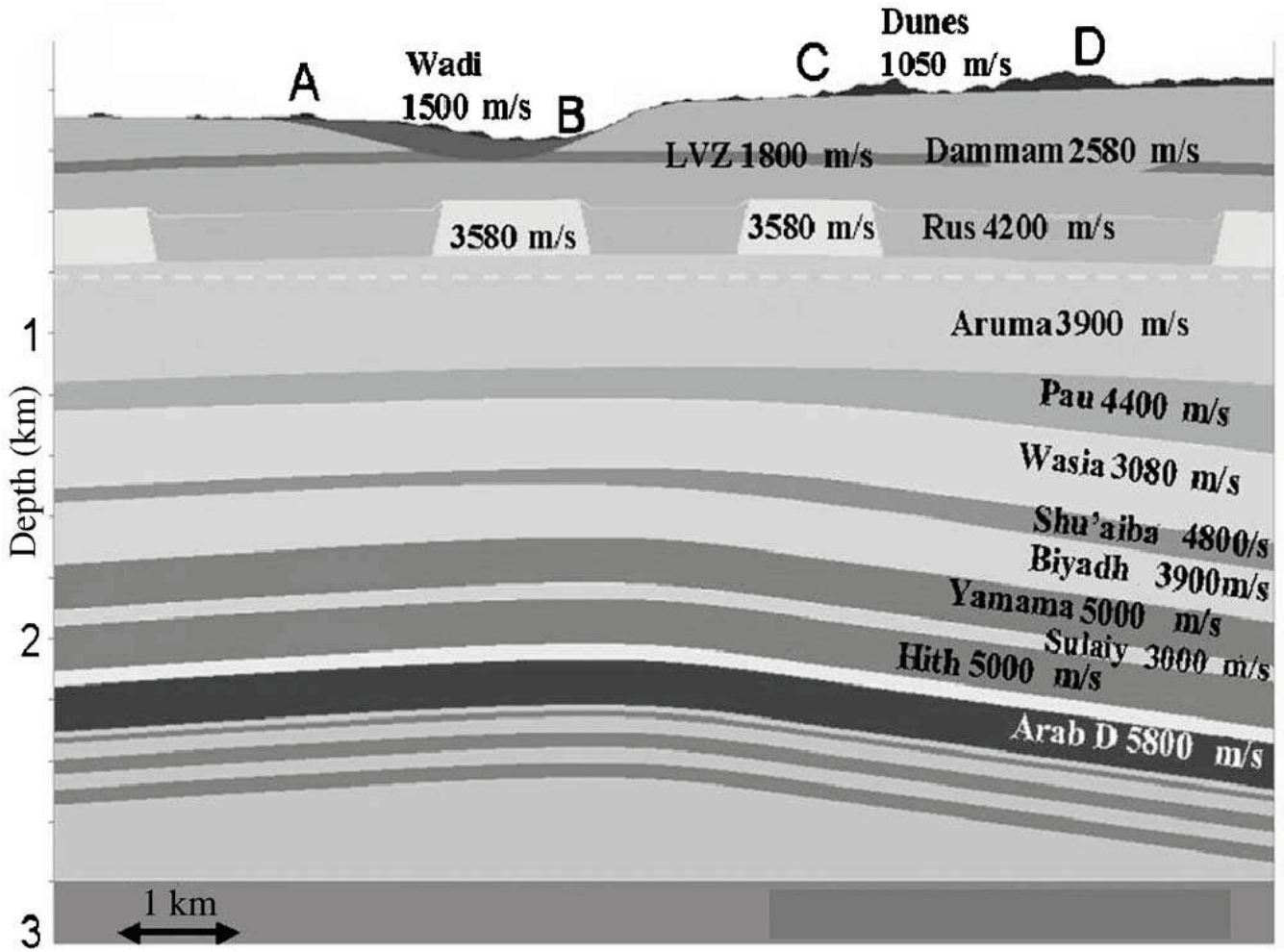
where ρ is the density, K is the bulk modulus, P is the wave field and S is the source term.

$$\nabla\epsilon(x,z,\omega)=\frac{1}{2}\sum_s\sum_r Re\{G_s^*(x,z,\omega)G_r^*(x,z,\omega)\delta d\}$$

$$m^{(l+1)}=m^{(l)}-\alpha^{(l)}\nabla\epsilon^{(l)}$$

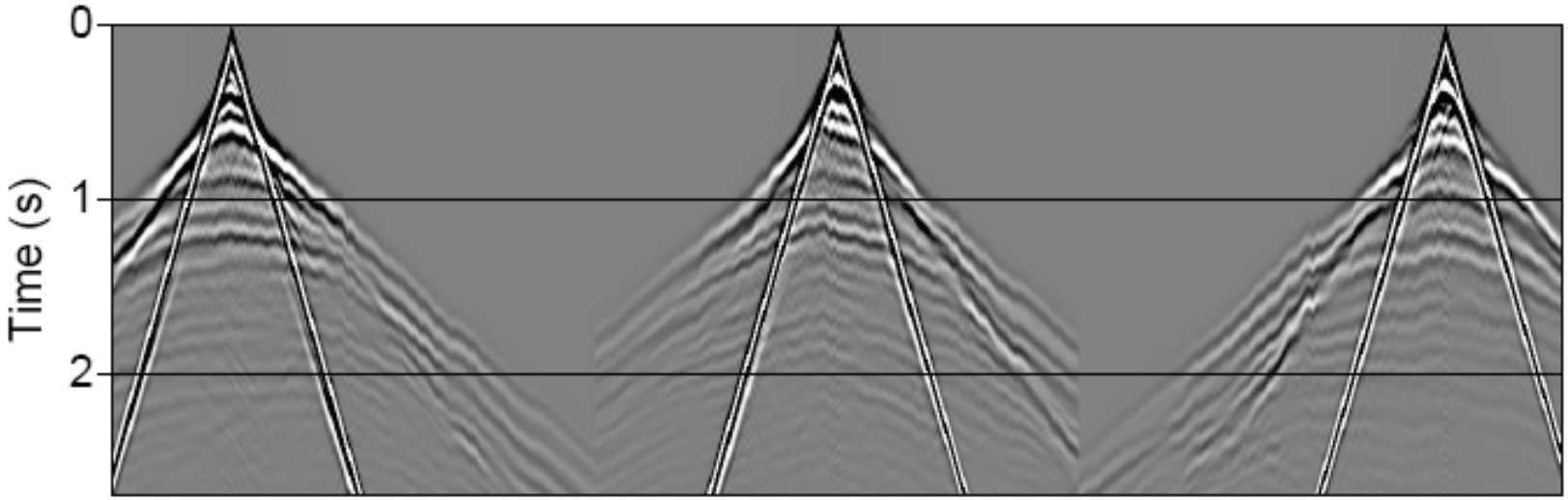
Lailly (1983), Tarantola (1984), Sirgue and Pratt (2004)

Saudi Aramco Model

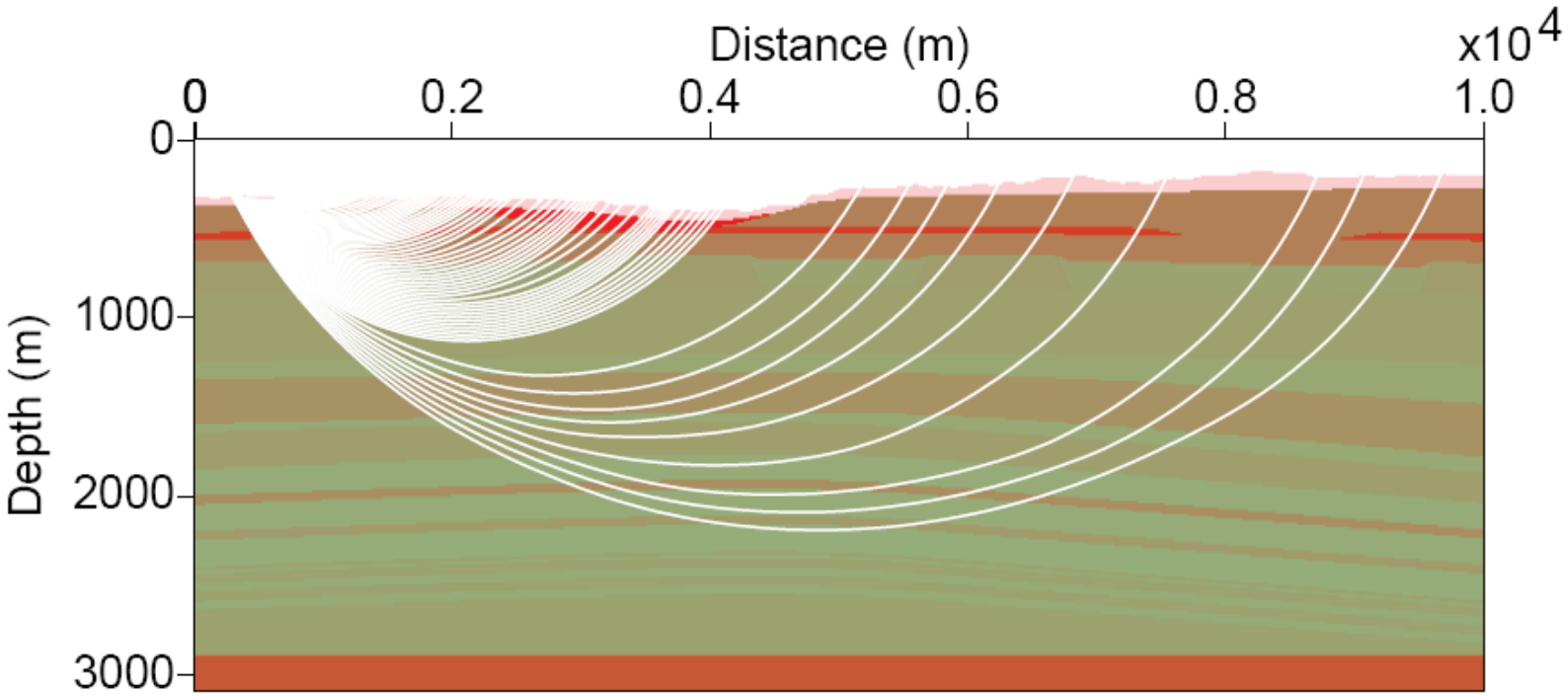


Alkhalifah and Bagaini (2006)

Sample shots



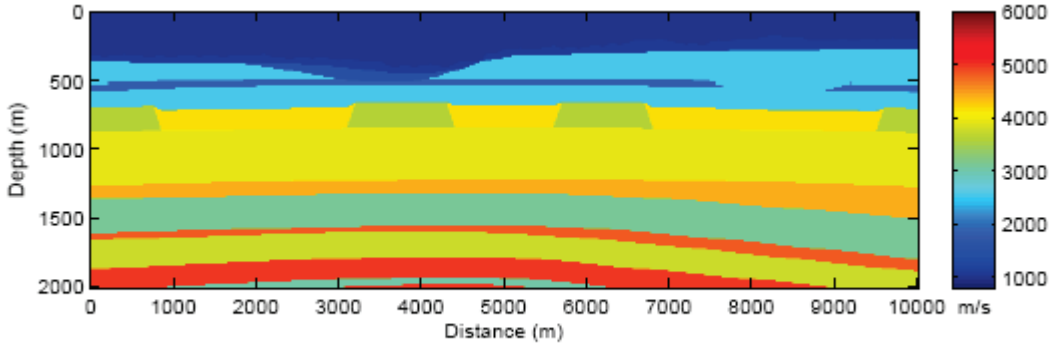
Max Depth



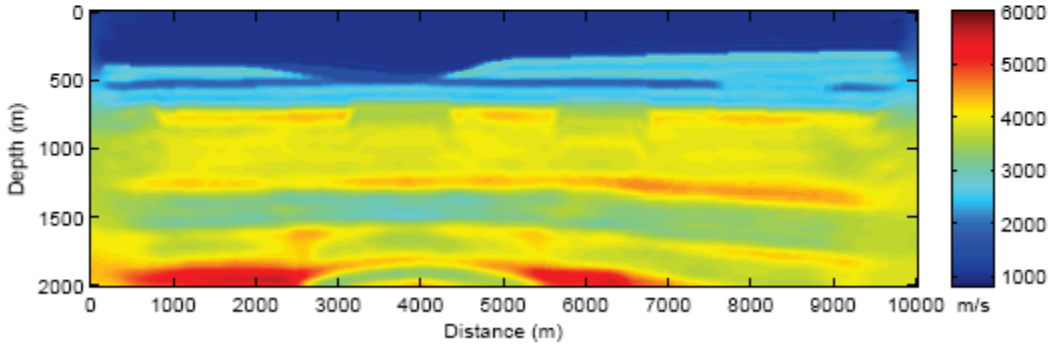
Parameters

- 2-14.8 HZ with 0.2 Hz interval
- 320 iterations, 5 per frequency
- Preconditioning in the wave-number domain (Sirgue, 2003)

Sequential strategy: results

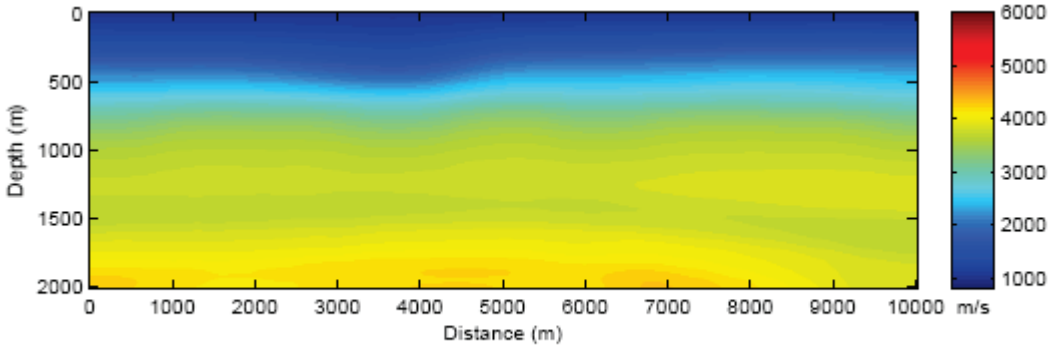


(c) True Model

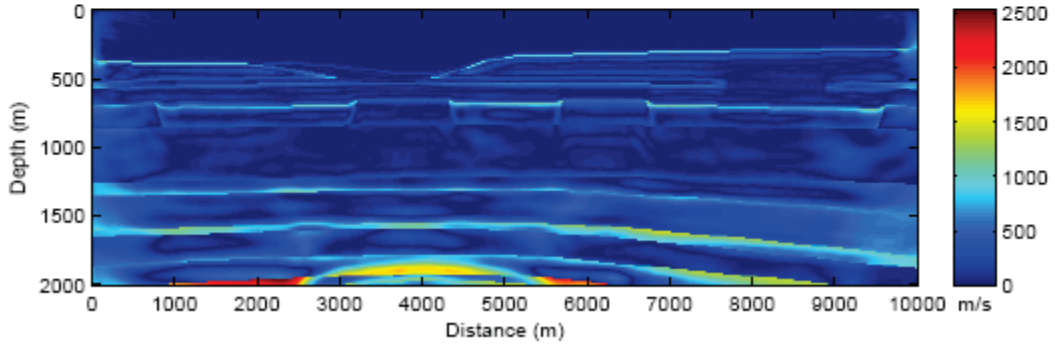


(b) Estimated Model

Sequential inversion: results

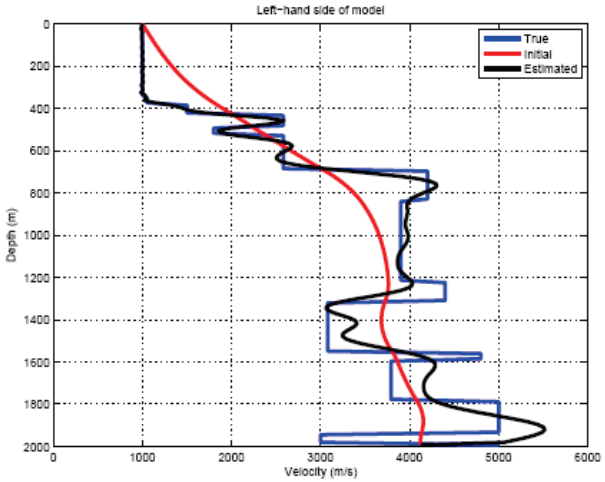


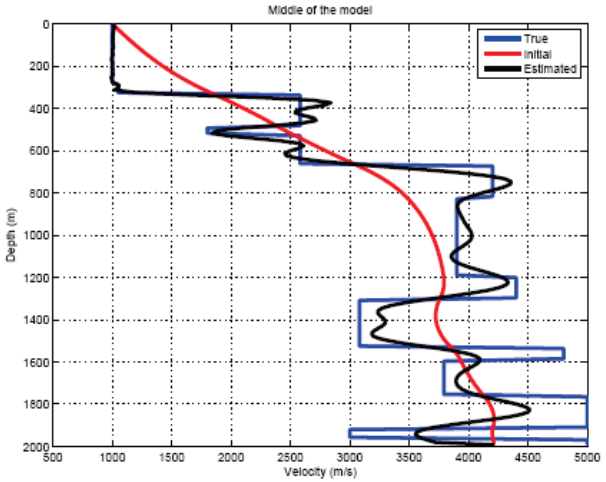
(a) Initial Model

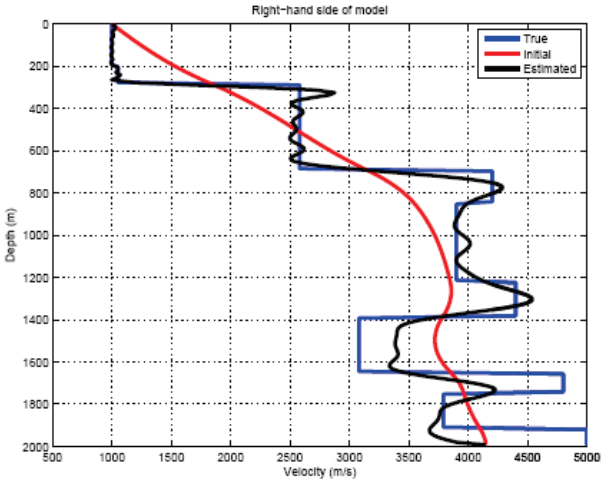


(d) Absolute Value of the Difference

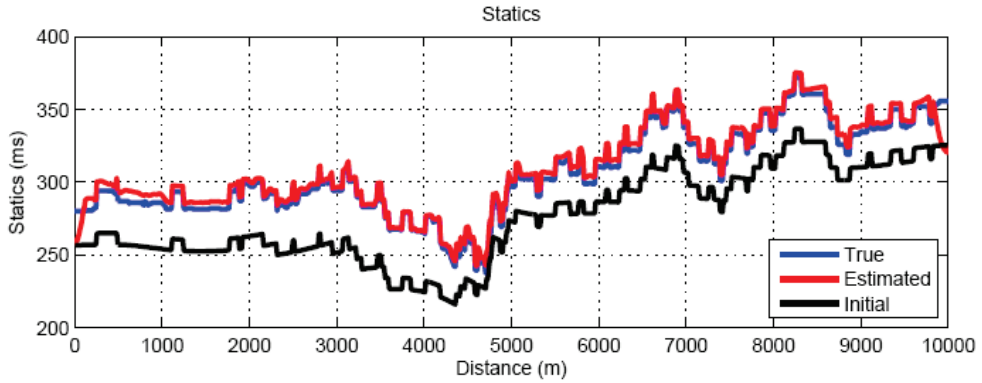
Sequential inversion: results



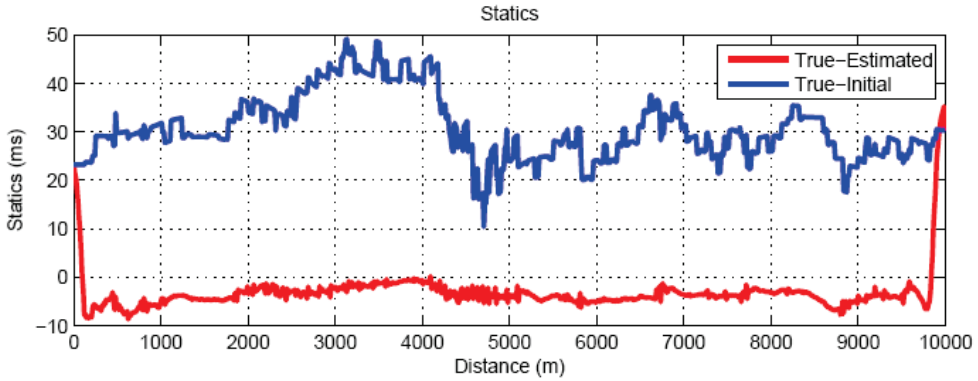




Sequential strategy: statics



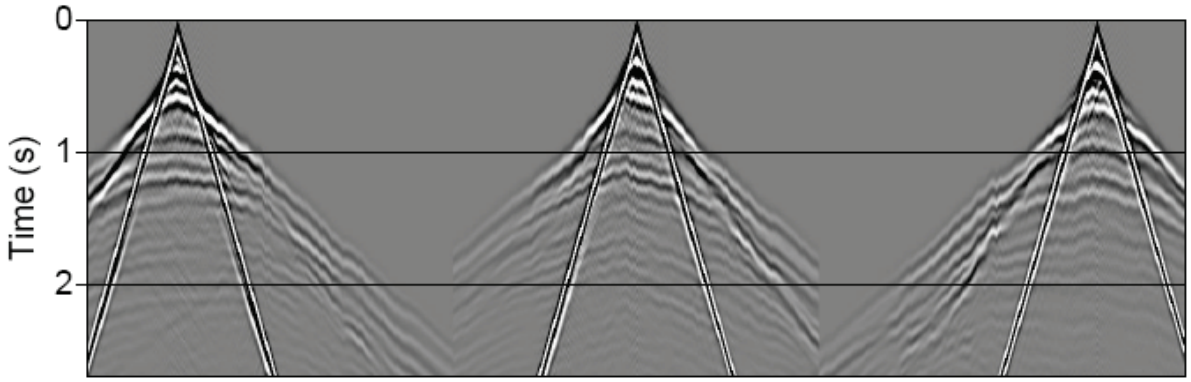
(a)



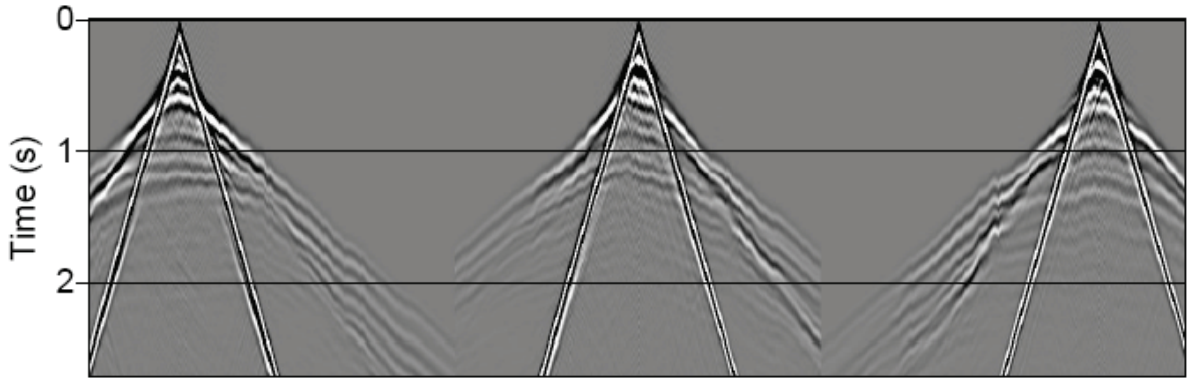
(b)

Data Comparison

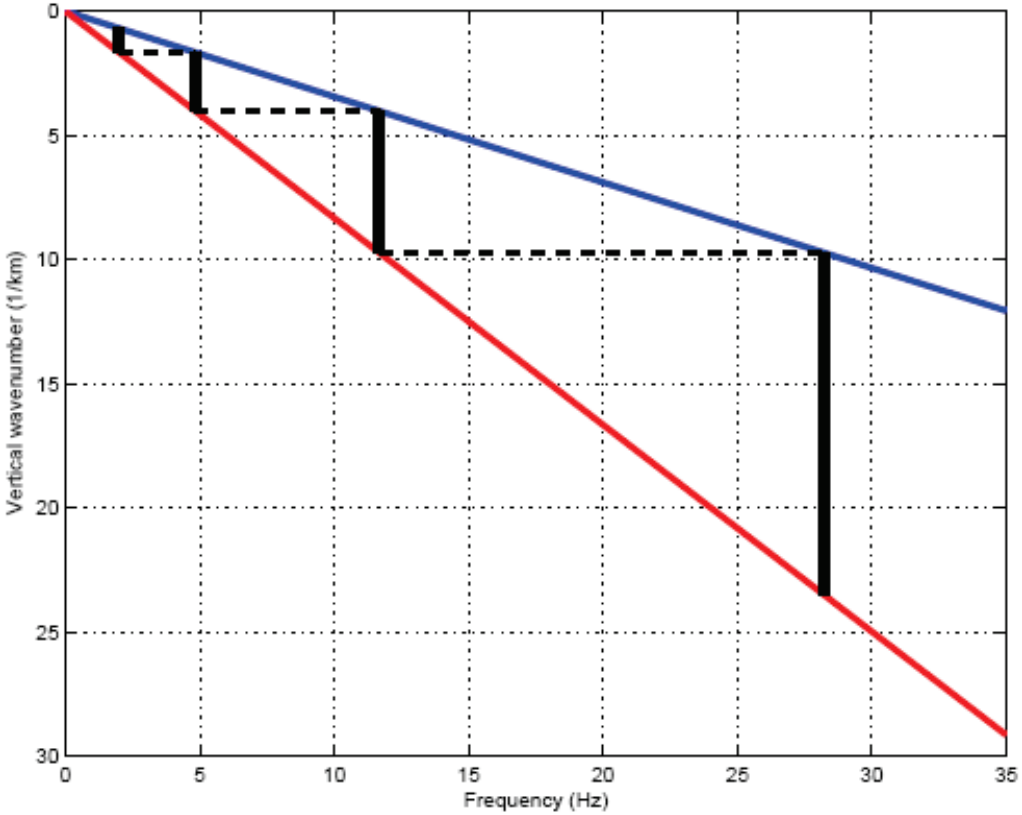
Observed data



Predicted data



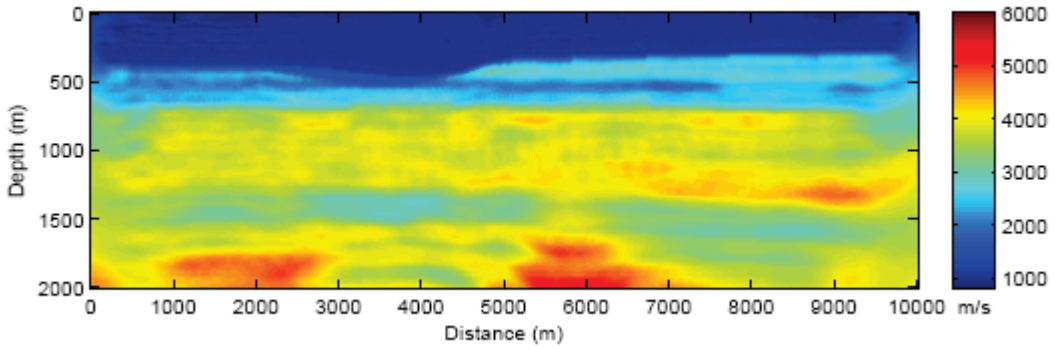
Efficient Strategy



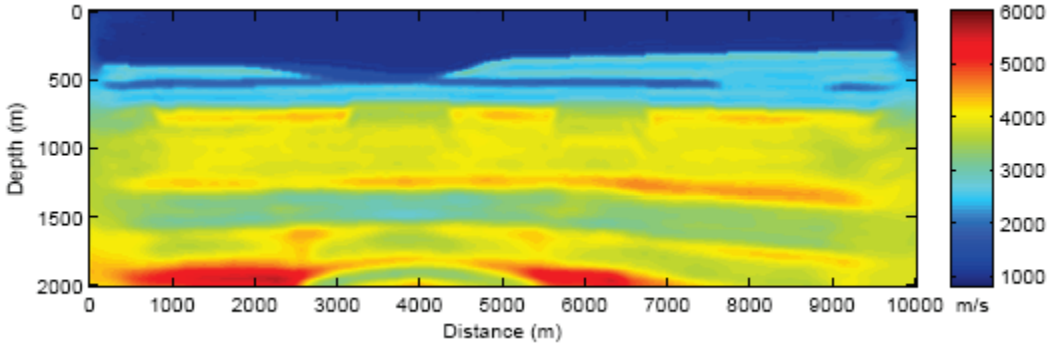
Similar to Sirgue and Pratt (2004)

Efficient Strategy: results

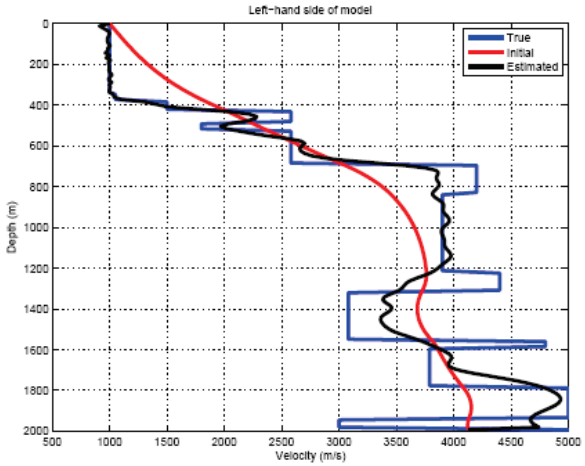
Efficient strategy

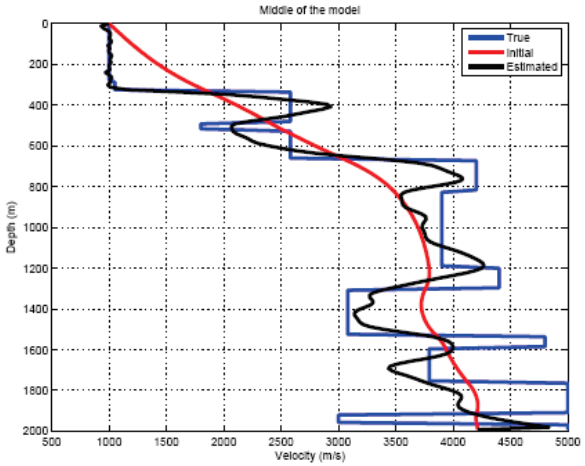


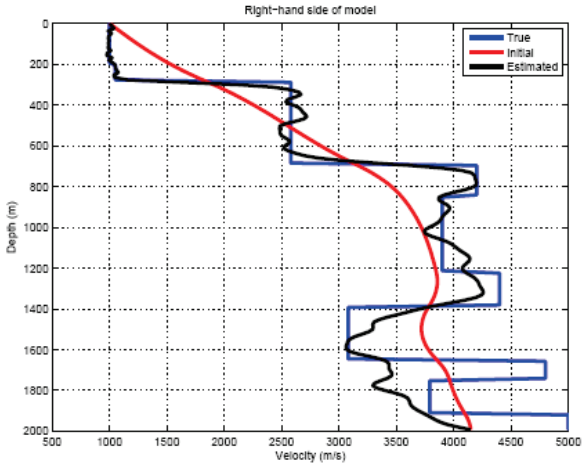
Sequential strategy



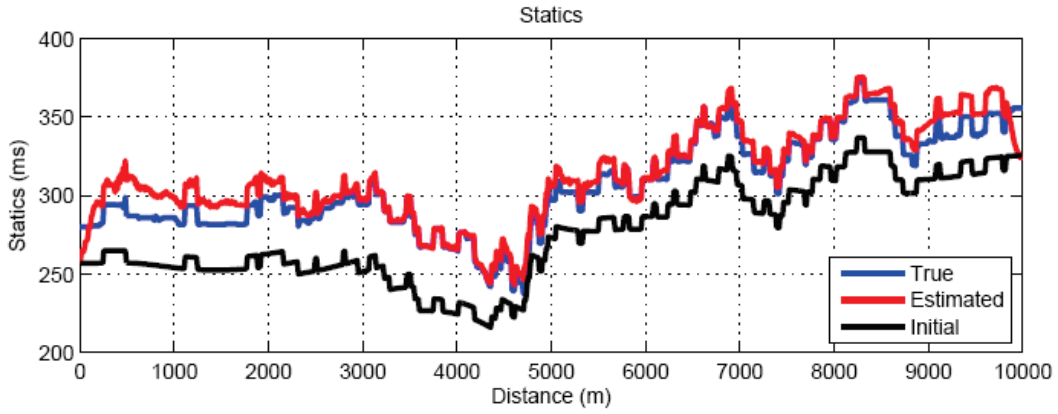
Efficient Strategy: results



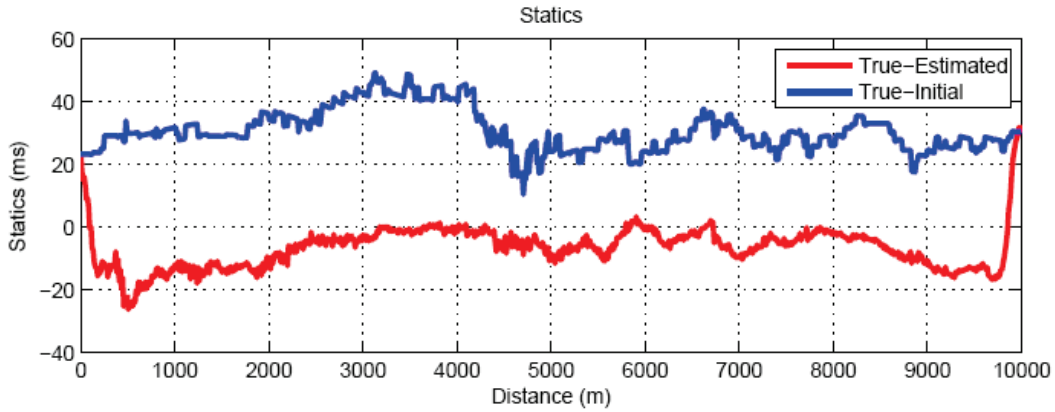




Sequential strategy: statics



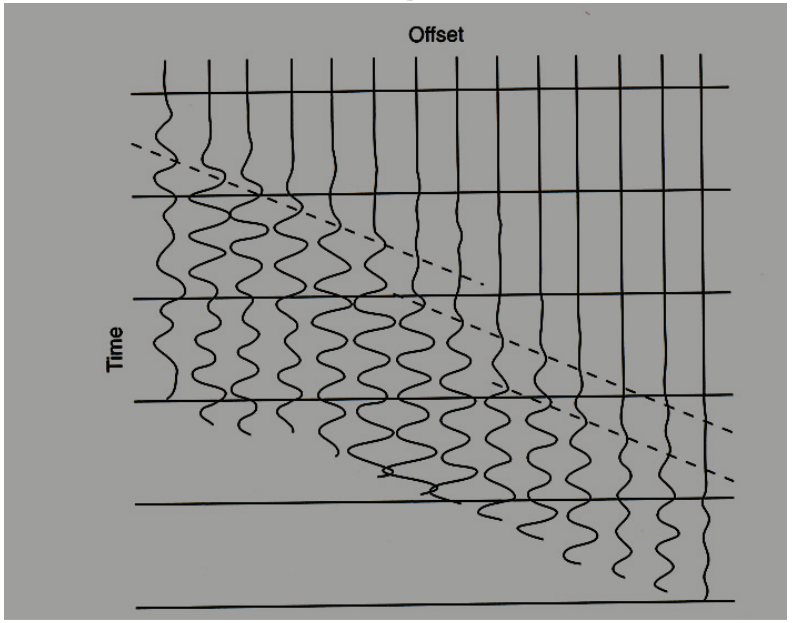
(a)



(b)

Shingling

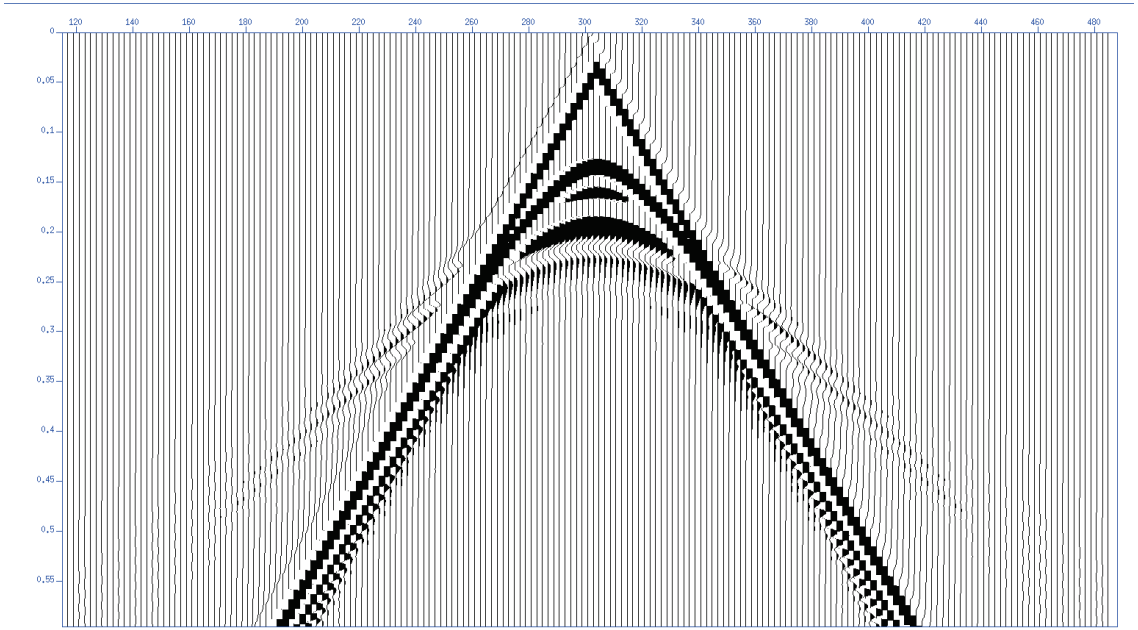
- Definitions: “ Shingling, a phenomenon characterized by a shift of energy to successively later cycles as the offset increases producing an en echelon pattern.”

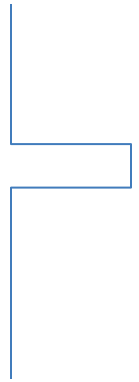


Cox (1999, p. 158)

See also Sheriff and Geldart (1995, p. 169)

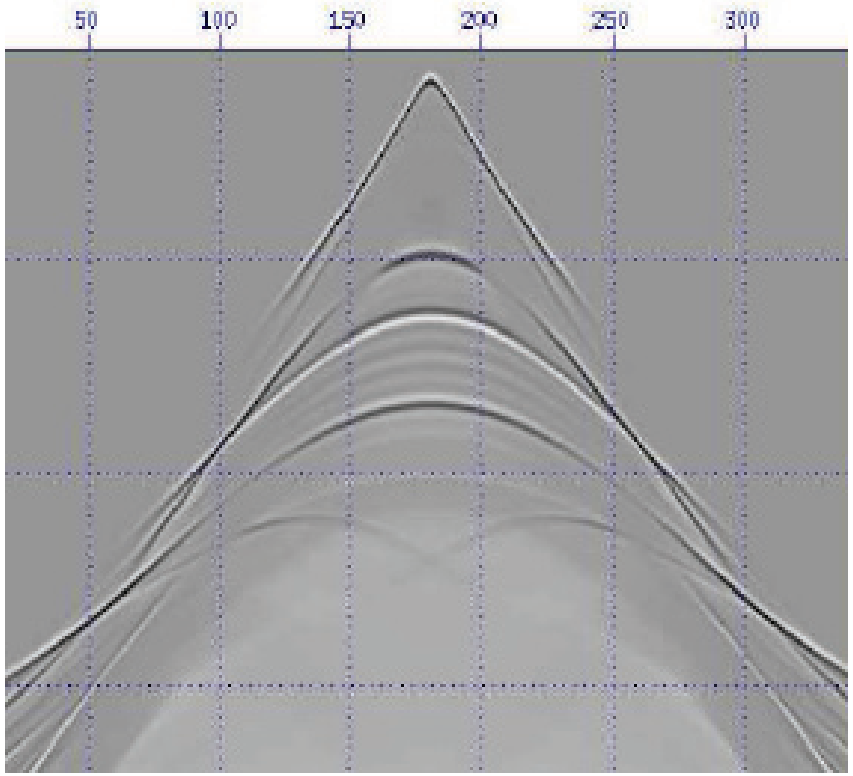
One layer

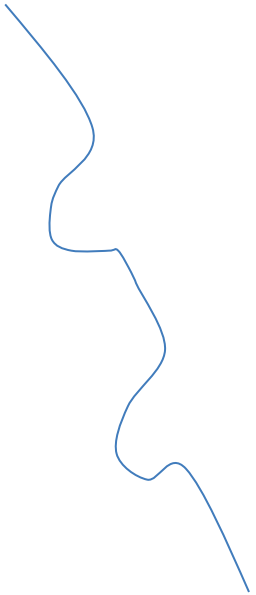




Model

Shingling with gradient

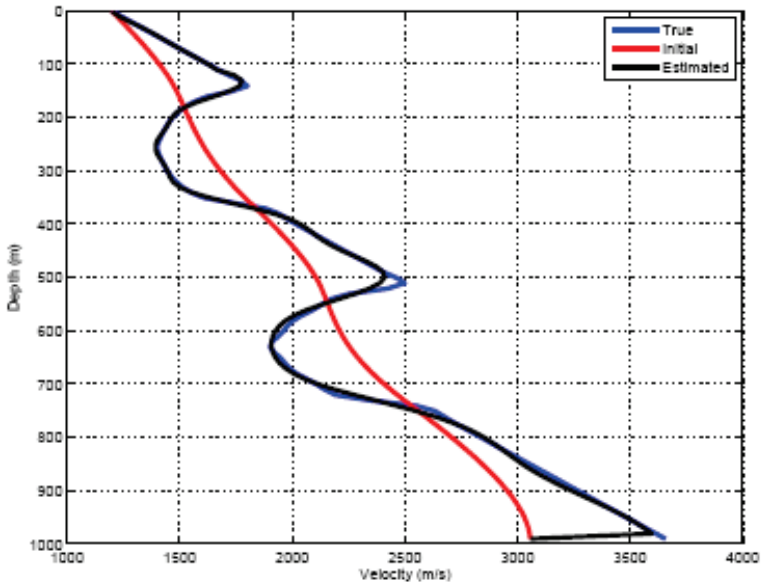




Model

Thanks to Yi Lu, Saudi Aramco

Inversion results



Conlusion

- Waveform tomography (WT):

  1. Successful inversion of complex near surface.
  2. Better statics -> better delineation of the subtle feature, low relief-structure.
  3. confirmation of this subtle feature with inverted velocities themselves.
  4. Quantification of the velocities of the target.

- WT can potentially resolve shingling.

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