Tomographic inversion of P-waves for TTI media: Application to field data

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Assumption: symmetry axis orthogonal to reflector
P-Wave NMO Velocity in TTI Layer
Symmetry Axis Orthogonal to Reflector

Parameters: $V_{P0}$, $\epsilon$, $\delta$, $\nu$

$$V_{nmo}(\nu) = \frac{V_{nmo}(0)}{\cos \nu} = \frac{V_{nmo}(0)}{\sqrt{1 - \rho^2 V_{P0}^2}}$$

$$V_{nmo}(0) = V_{P0} \sqrt{1 + 2\delta}$$

$$\rho = \frac{\sin \nu}{V_{P0}} \quad \text{(ray parameter)}$$
Model representation

- regular grids
- $V_{p0}$, $\varepsilon$, $\delta$, and tilt $\nu$
- $\nu$: from depth image
Objective function

- flattening image gathers
- minimizing VSP traveltime misfit
- regularization

(Liu, 1997; Sarkar & Tsvankin, 2004)
Residual moveout in CIGs

\[ z^2(h) = z^2(0) + Rh^2 + S \frac{h^4}{h^2 + z^2(0)} \]

- \( h \): half-offset
- \( z \): migrated depth

![Diagram showing near- and far-offsets with formulas and labels](image)
Workflow

only $V_{P0}$ update

quasi-factorized model ($\varepsilon$ and $\delta$ layer-based)

fully gridded model
BP TTI model (salt section)

reflection data + VSP traveltimes + check shots
Inverted model (fully gridded)

$V_{P0}$ (m/s)

grid size: 200 m × 100 m
Image with inverted model
Volve Field, North Sea

(figure courtesy of Statoil)
Well trajectories
Well trajectories

$y = 2.8$

Well 2

Well 1
Initial model
(check shots + extrapolation)
Initial model
(check shots + moveout inversion)
Initial model
(check shots + moveout inversion)
CIGs for initial model
Inverted TTI model

grid size: 100 m × 50 m
Statoil’s VTI model
Inverted TTI model
Statoil’s VTI model
Inverted TTI model
Statoil’s VTI model
CIGs for inverted model
CIGs for initial model
Image with inverted model
Image with inverted model
Image with Statoil’s VTI model
Summary

- TTI tomography of reflection and VSP data
- structure-guided regularization
- three-stage parameter updating stabilizes inversion
- improved images for Volve field
- key horizons tie well markers
- extensions: wide-azimuth data, orthorhombic models
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