A New, Integrated Velocity Solution for Interpreters
Paradigm Time Preserving Tomography

Masako Robb
Time Preserving Tomography (TPT)

- A **post-stack** depthing tool for interpreters to improve seismic-to-well misties
- **Refines** the original, mis-tied velocity model in a more *geologically plausible* way
- Produces a matched, tied set of markers, interpretation, velocity and seismic
- A **fast** and **easy**, yet more **sophisticated** methodology than traditional approaches
Issues – Misties in Depth

- Interpret in depth on PSDM, have issues with depth surfaces tying depth markers…
- Interpret in time on PSTM, scale results to depth using seismic velocity, get misties…
- Interpret in time on PSTM, use well velocity (krigging, layer cake velocity model, $V_0$-$K$…), still get misties after scaling to depth
- How do we handle this issue…?
Velocity Refinement

Goal:
- To Reduce misties
- Geologically plausible
- No velocity anomaly
- No distortion in seismic
- Repeatable, non-subjective way
Time Preserving Tomography (TPT)

- TPT uses the concept of seismic reflection tomography (that traditionally requires pre-stack gathers)

But…!!

- TPT is a post-stack solution, and does not require pre-stack gathers

Solution for interpreter
Short Primer - What is Seismic Reflection Tomography?
Seismic Reflection Tomography – An Inversion

- An analogy…Impedance inversion
- Start point: Observe seismic reflectivity behavior caused by some unknown impedance model
- Low detail, constraining background model is globally updated and errors are minimized
- End point: Updated, detailed impedance model that must have caused those reflectivity contrasts
(Prestack) Seismic Reflection Tomography

- **Start point:** Observe gather flatness behavior caused by some unknown velocity model
- **Low detail,** constraining background model is globally updated and errors are minimized
- **End point:** Updated, detailed velocity model that must cause the gathers to be flat
(Prestack) Seismic Reflection Tomography

- Start point: Observe gather flatness behavior caused by some unknown velocity model
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Global Update + Ray Tracing
(Prestack) Seismic Reflection Tomography

- Challenge: The non-uniqueness of the solution
Seismic Reflection Tomography with Well Constraint

- Additional constraint: Mistie Maps

Tomography equation in the welltie mode

\[ A_S \delta S + A_\eta \delta \eta + A_\delta \Delta \delta + \sum_l A_Z \delta Z_l = \delta t \]

Velocity error | Epsilon error | Delta error | Depth error | Traveltime error

\[
\begin{pmatrix}
\Delta t_1 \\
\Delta t_2 \\
\Delta t_3 \\
\vdots \\
\Delta t_M
\end{pmatrix} =
\begin{pmatrix}
A_{v_{11}} & A_{z_{11}} & A_{\delta_{11}} & A_{\epsilon_{11}} & \cdots & A_{v_{1N}} & A_{z_{1N}} & A_{\delta_{1N}} & A_{\epsilon_{1N}} \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\
A_{v_{M1}} & A_{z_{M1}} & A_{\delta_{M1}} & A_{\epsilon_{M1}} & \cdots & A_{v_{MN}} & A_{z_{MN}} & A_{\delta_{MN}} & A_{\epsilon_{MN}}
\end{pmatrix}
\begin{pmatrix}
\Delta v_1 \\
\Delta z_1 \\
\Delta \delta_1 \\
\Delta \epsilon_1 \\
\vdots \\
\Delta v_N \\
\Delta z_N \\
\Delta \delta_N \\
\Delta \epsilon_N
\end{pmatrix}
\]

Coefficients found along traced ray

**Inputs:** RMOs From Dept \( h \) migrated gathers

**Outputs:** tomography solution: Residual Medium parameters and model depth shift (MB)
Must have prestack data?
Must have a cluster computer?
Time Preserving Tomography

Must have prestack data?

Must have a cluster computer?
\[ 0 = \Delta t = A_v \Delta \nu + A_\delta \Delta \delta + A_\varepsilon \Delta \varepsilon + A_z \Delta z \]
TPT – Input and Output

- **Input:**
  - Background model
  - Mistie maps ($dz$)

- **Output:**
  - Updated model
  - Updated depth maps
## TPT - Workflow

- Generate Mistie Maps
- Generate Pencils
- Run Time Preserving Tomography
- QC Updated Velocity and Depth Models

### Mistie?

<table>
<thead>
<tr>
<th>Application Mode</th>
<th>Build Matrix</th>
<th>Time-Preserving</th>
</tr>
</thead>
</table>

| Select Pencil File | pt_pencil1 |

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Updated Model Type</th>
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<tbody>
<tr>
<td>ISO</td>
<td>VTI</td>
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### Input Volumes Files

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<tr>
<th>Interval Velocity</th>
<th>Select...</th>
<th>Instantaneous Velocity vs Depth</th>
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</thead>
<tbody>
<tr>
<td>Delta</td>
<td>Select...</td>
<td></td>
</tr>
<tr>
<td>Epsilon</td>
<td>Select...</td>
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</tr>
<tr>
<td>Anisotropy Dip</td>
<td>Select...</td>
<td></td>
</tr>
<tr>
<td>Anisotropy Azimuth</td>
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</table>
TPT - Workflow

Create Initial Interval Velocity
Scale Horizons to Depth
Generate Mistie Maps
Generate Pencils
Run Time Preserving Tomography
QC Updated Velocity and Depth Models

Mistie?

- Application Mode
  - Build Matrix
  - Time-Preserving

- Select Pencil File: pt_pencil1

- Model Type
  - ISO
  - VTI
  - TTI

- Updated Model Type
  - ISO
  - VTI
  - TTI

- Input Volumes Files
  - Interval Velocity
  - Delta
  - Epsilon
  - Anisotropy Dip
  - Anisotropy Azimuth

- Instantaneous Velocity vs Depth

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Mistie?
Example - Taranaki Basin
Mistie Maps (Before Tomography)

Mistie Range (-180 ~ 20 m)
Original Velocity and Depth Model
Updated Velocity and Depth Model
Updated Velocity and Depth Model, Seismic
Original Velocity and Depth Model, Seismic
Flexibility of Tomography

- Can update only a single formation (such as within a channel velocity) if required
- Can choose different update/smooth parameters per formation
- Can use velocity/anisotropy misties as input instead of depth misties
Time Preserving Tomography Benefits

- A global inversion process which uses ray tracing, while other solutions are local and use vertical scaling
- Suitable for the most complex velocity model
- Simple, GUI-driven, post-stack workflow
- Takes account of anisotropy
Application to Pull Up/Down Effects

Pitfalls in seismic Data interpretation

a) 3D Kirchhoff preSDM using initial velocity model

Channel not visible, but deeper distortion is obvious

b) preSDM using channel velocity=1900m/s

Ian Jones, First Break, March 2012
Application to Pull Up/Down Effects

Example: Low Velocity Intrusion in Salt

Mistie information is used to update Intrusion only
Application to Pull Up/Down Effects

Example: Salt Intrusion

Model Velocity
Input Velocity Salt Flooded
Updated Velocity From TP tomography
Thank you
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