Fault Flooding Migration Project

Ahmed Metwally **Maximillian Kosmicki**

Earth Science and Engineering Department (ErSE), King Abdullah University of Science and Technology (KAUST).

Outline

- Motivation: Finding Steeply Dipping Faults
- Theory: ‘Fault Flooding’ Method
- Workflow: Overview of Steps
- Synthetic Data Trial: Vertical Fault Example
- Gulf Of Aqaba Data: Field Data Results

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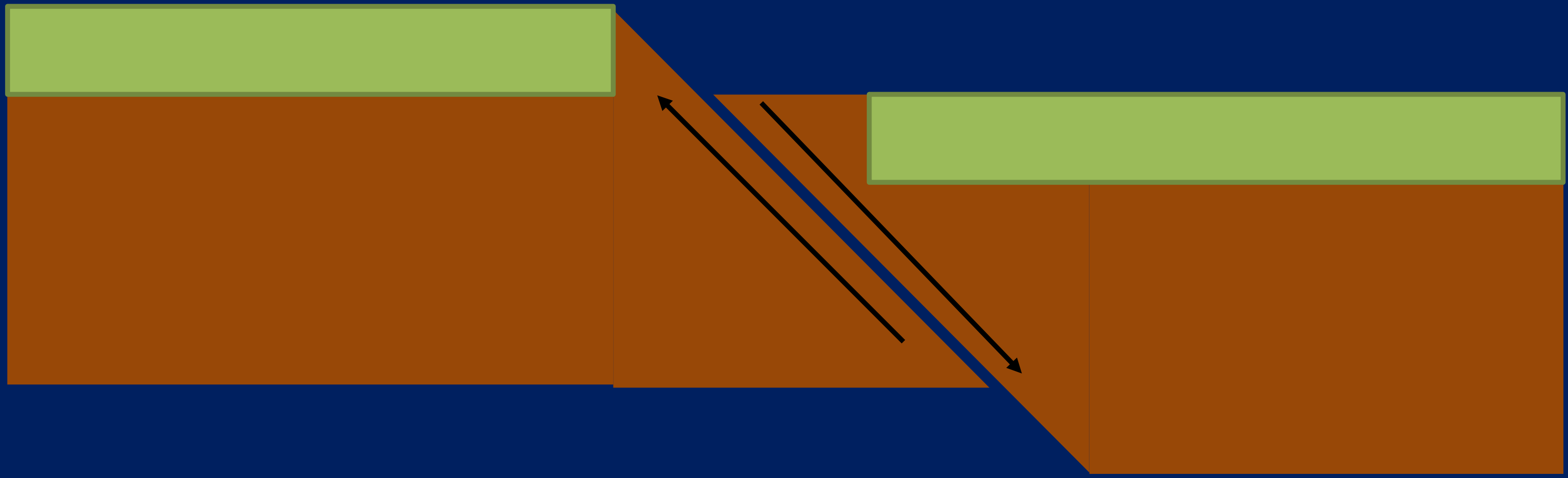
Motivation



To accurately obtain fault parameters using seismic data.

- Implications for Seismology and Civil/Geological Engineering

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Theory

The migration equation for imaging the fault is given by:

$$m(\mathrm{x}) \;=\; \sum_{\omega}\sum_{s}\sum_{g}\sum_{g'} \Phi(\mathrm{g},\mathrm{g}',\mathrm{s},\omega)e^{-i\omega(\tau^{2}_{xg}-\tau^{1}_{xg'})}.$$

This equation. is equivalent to interferometric-ally detecting the location of a point source (Schuster, 2009) at xo, except now the source is at the location of the fault boundary.

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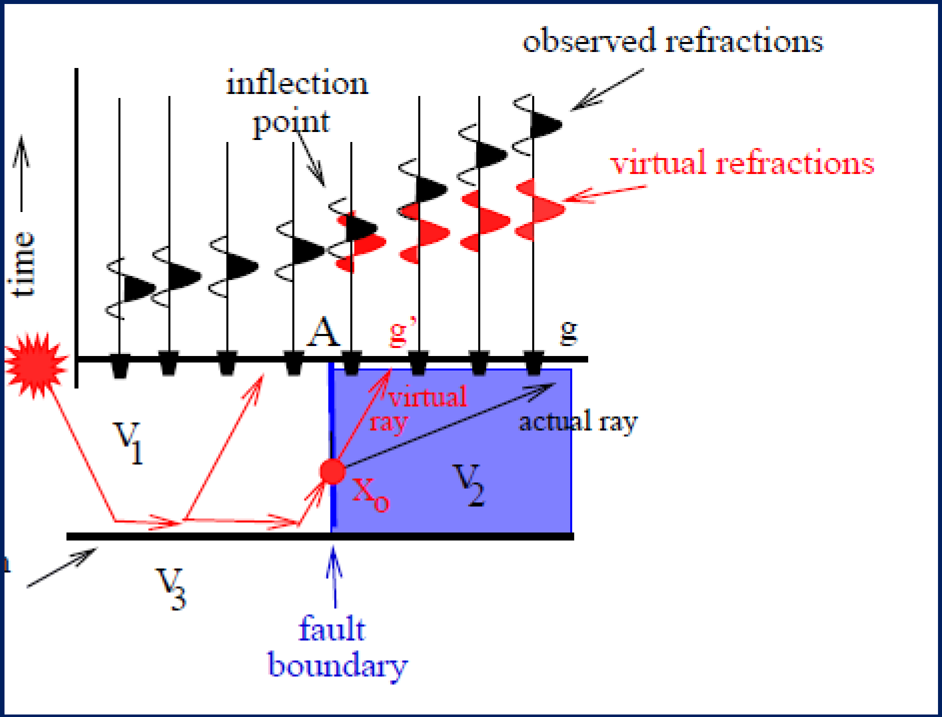
Workflow

1. Identify and isolate the refraction events whose move out curve sharply bends at a common surface location for shot gathers with shots on one side of the fault.



$$D(\mathrm{g},\mathrm{s},\omega)_{obs} = e^{i\omega(\tau^1_{sx_o}+\tau^2_{x_og})}; \qquad D(\mathrm{g}',\mathrm{s},\omega)_{virt} = e^{i\omega(\tau^1_{sx_o}+\tau^1_{x_og'})},$$

Workflow

2. Correlate the recorded and virtual traces to give the correlated data:

$$\Phi(\mathrm{g},\mathrm{g}',\mathrm{s},\omega) \;=\; D(\mathrm{g},\mathrm{s},\omega)_{obs} D(\mathrm{g}',\mathrm{s},\omega)^{*}_{virt} = e^{i\omega(\tau^{2}_{x_{o}g} - \tau^{1}_{x_{o}g'})}.$$

3. Apply the migration kernel :

$$m(\mathrm{x}) \;=\; \sum_{\omega}\sum_{s}\sum_{g}\sum_{g'} \Phi(\mathrm{g},\mathrm{g}',\mathrm{s},\omega) e^{-i\omega(\tau^{2}_{xg} - \tau^{1}_{xg'})}.$$

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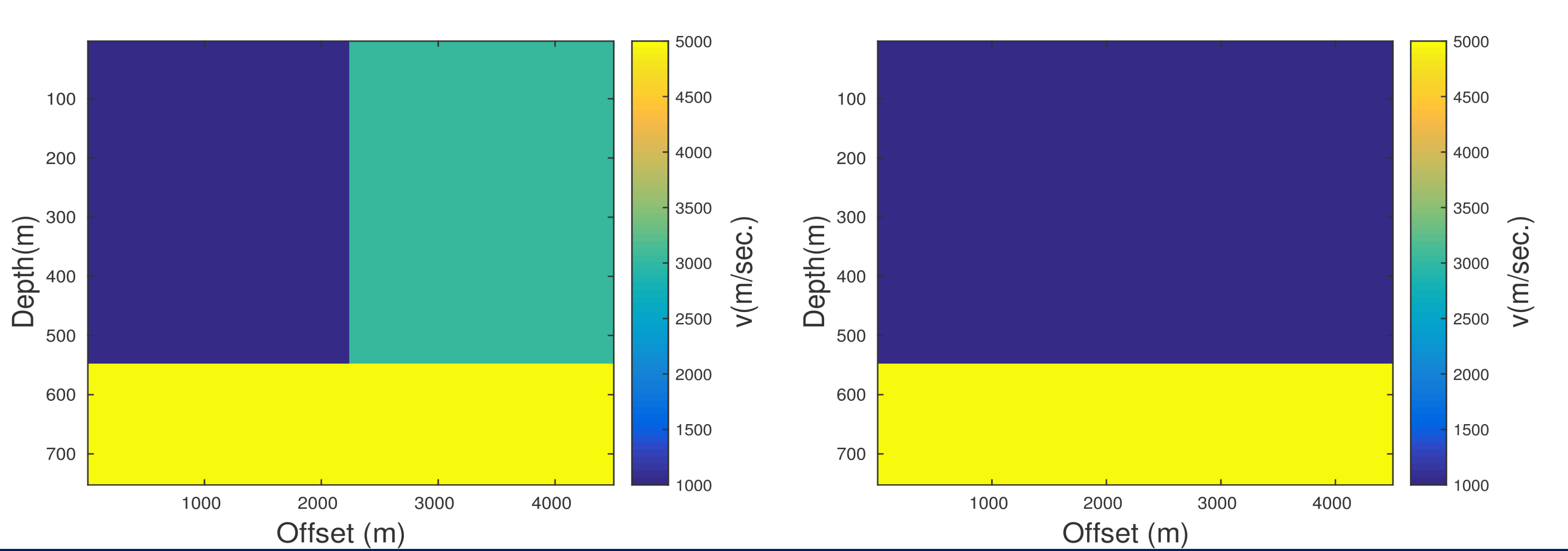
Synthetic Data Trial

Vertical Fault Example

1. Generate the synthetic data from the true velocity model and the ‘fault flooded’ virtual velocity model.

True velocity model **Virtual velocity model**

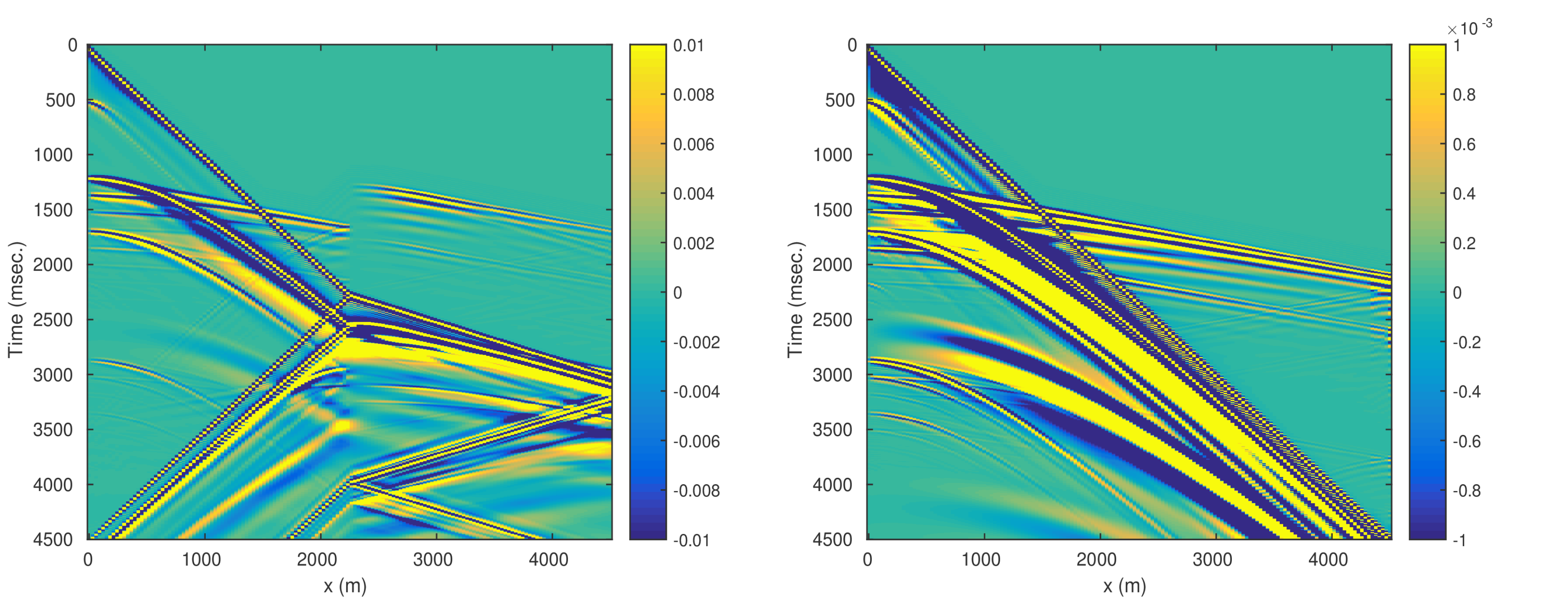


Synthetic Data Trial

Vertical Fault Example

2. Identify and isolate the refraction events in the datasets.

Observed data **Virtual data**

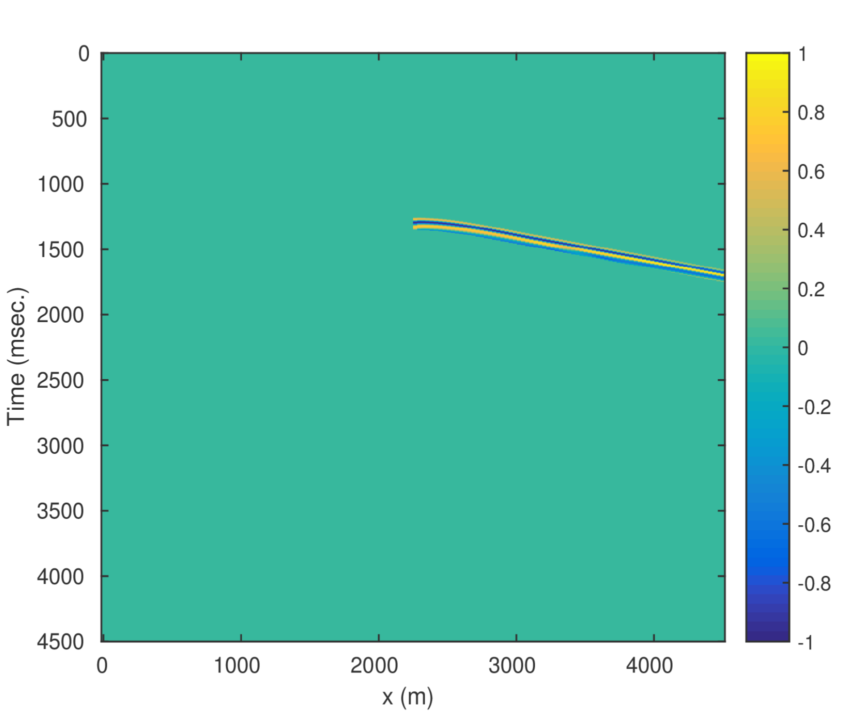


Synthetic Data Trial

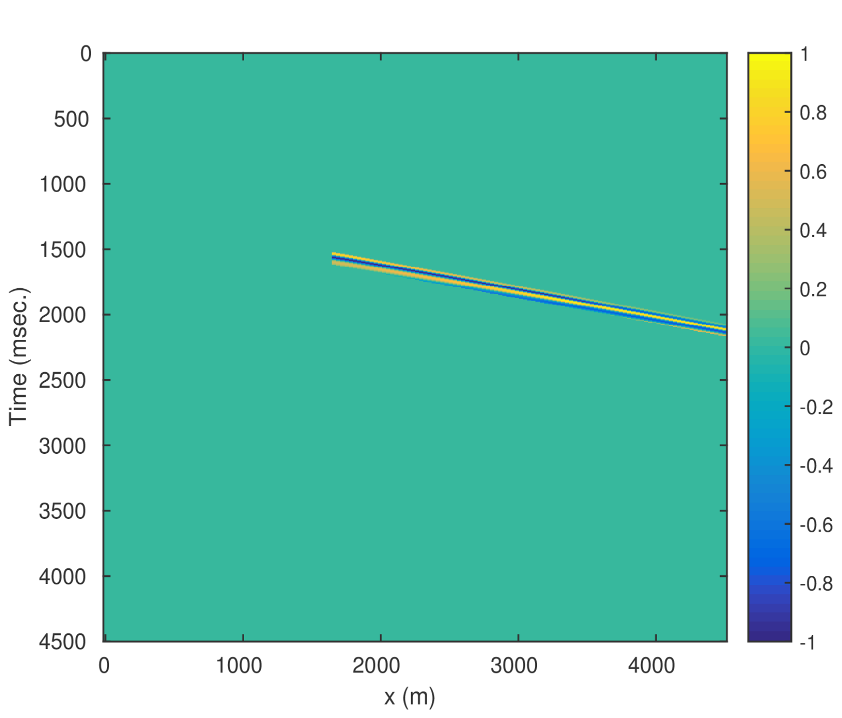
Vertical Fault Example

2. Identify and isolate the refraction events in the datasets.

Refractions only from observed data



Refractions only from Virtual data

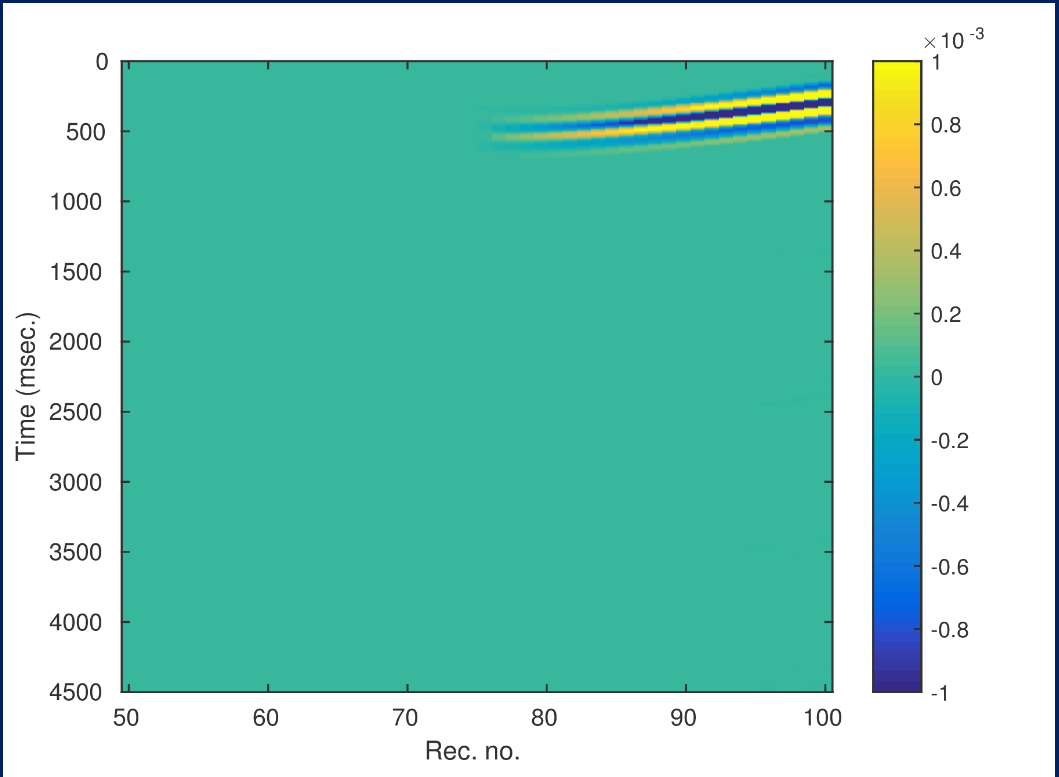


Synthetic Data Trial

Vertical Fault Example

3. Correlate the recorded (observed) and virtual traces to give the correlated data.

Cross Correlated Data

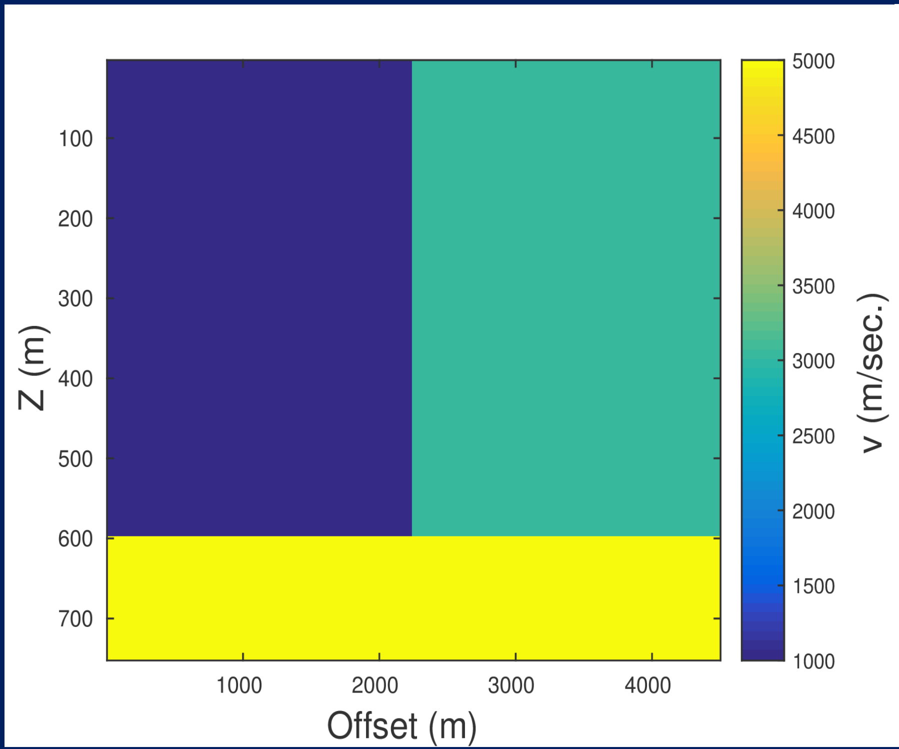


Synthetic Data Trial

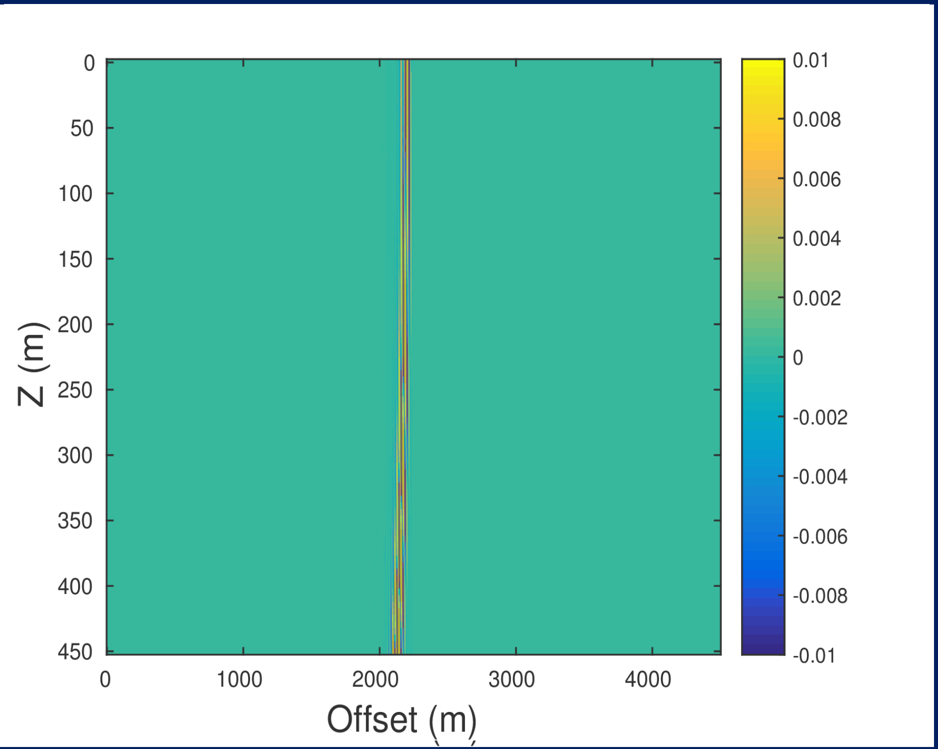
Vertical Fault Example

4. Apply the migration kernel to the cross correlated data.

True velocity model



Migration image for the fault



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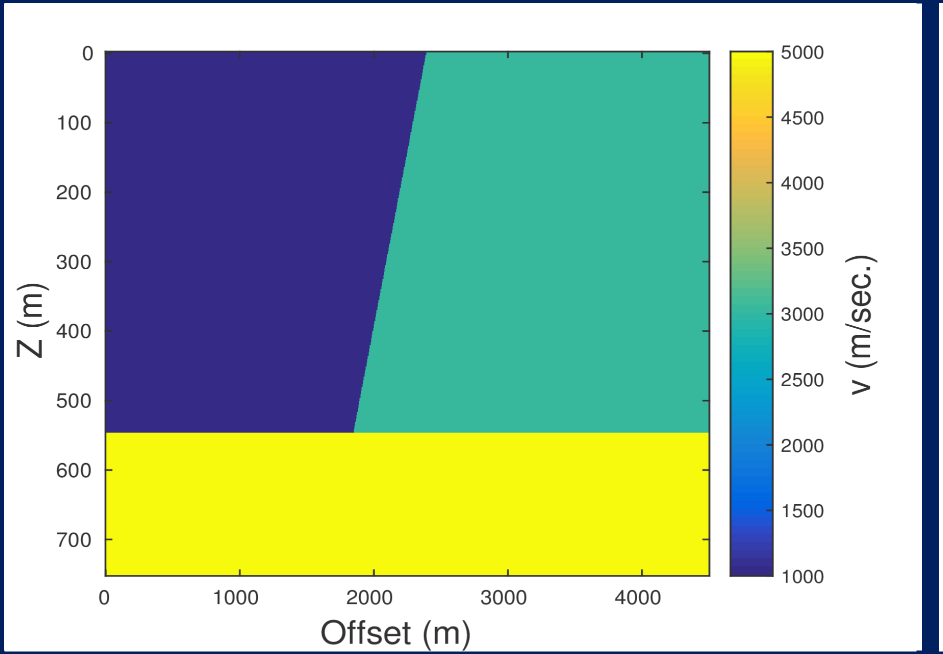
Synthetic Data Trial

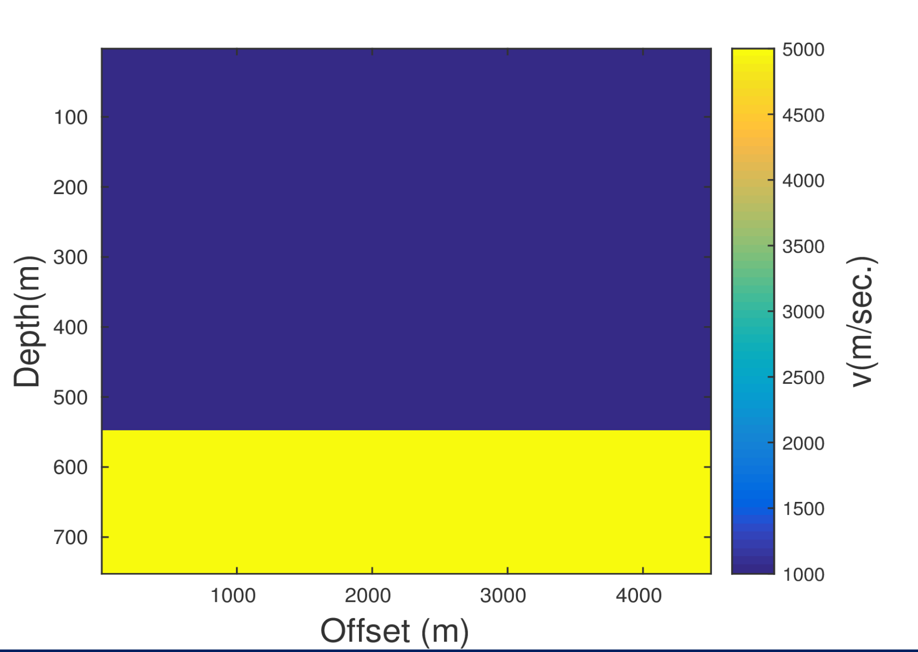
Tilted Fault Example

1. Generate the synthetic data from the true velocity model and the ‘fault flooded’ virtual velocity model.

True velocity model



Virtual velocity model

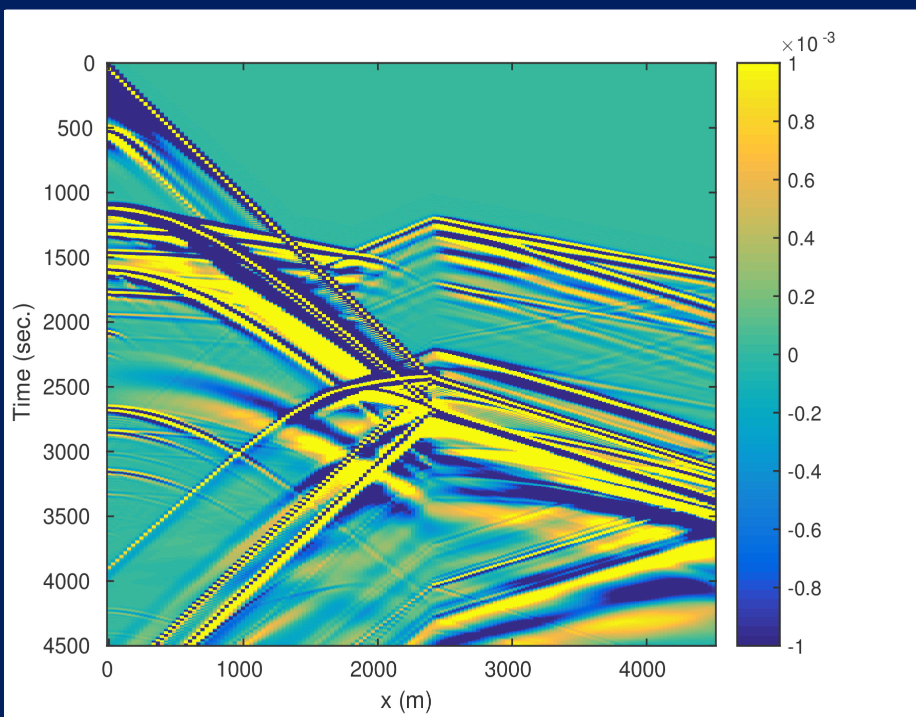


Synthetic Data Trial

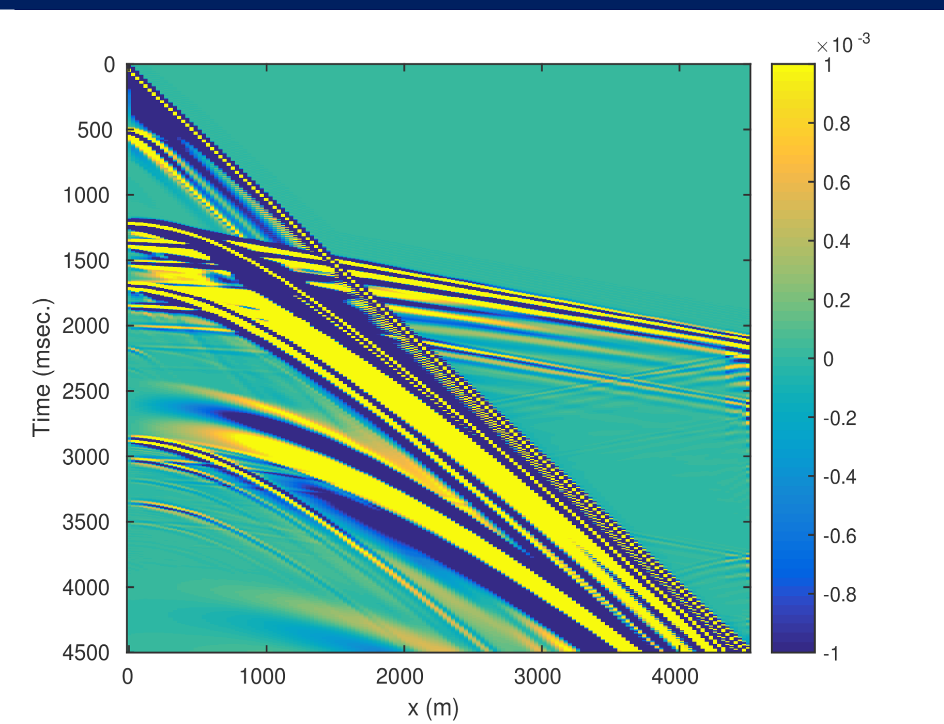
Tilted Fault Example

2. Identify and isolate the refraction events in the datasets.

Observed data



Virtual data

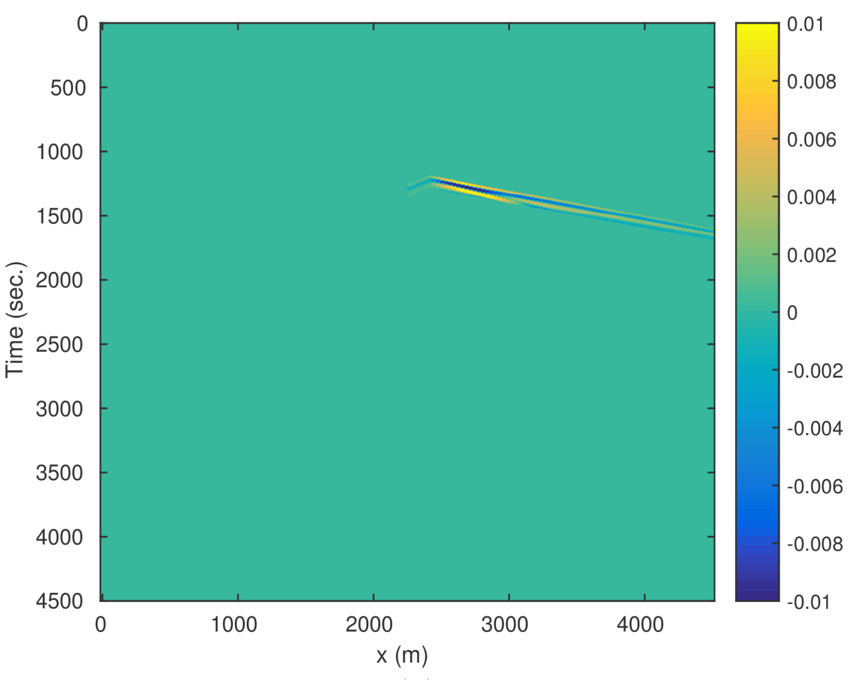


Synthetic Data Trial

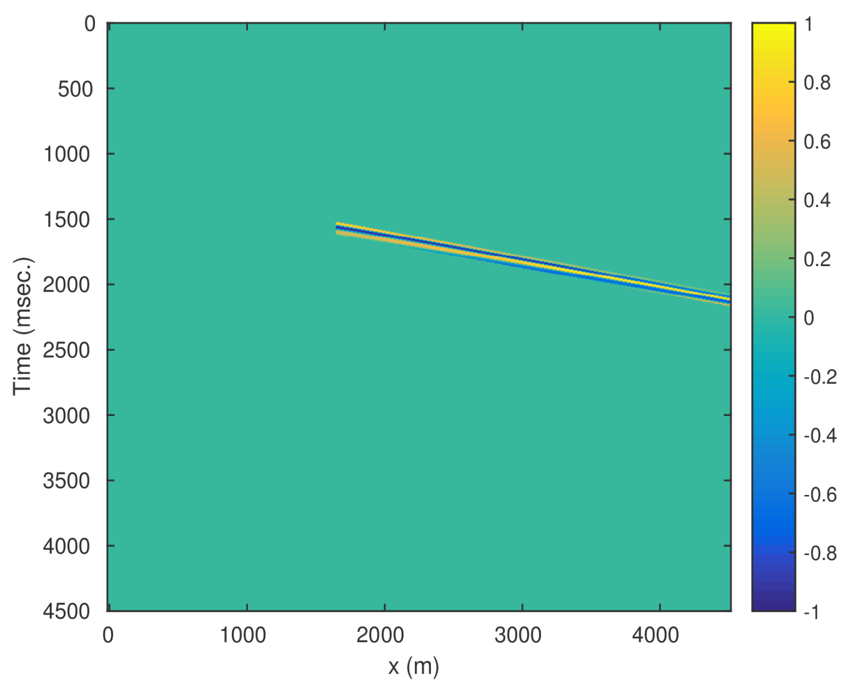
Tilted Fault Example

2. Identify and isolate the refraction events in the datasets.

Refractions only from observed data



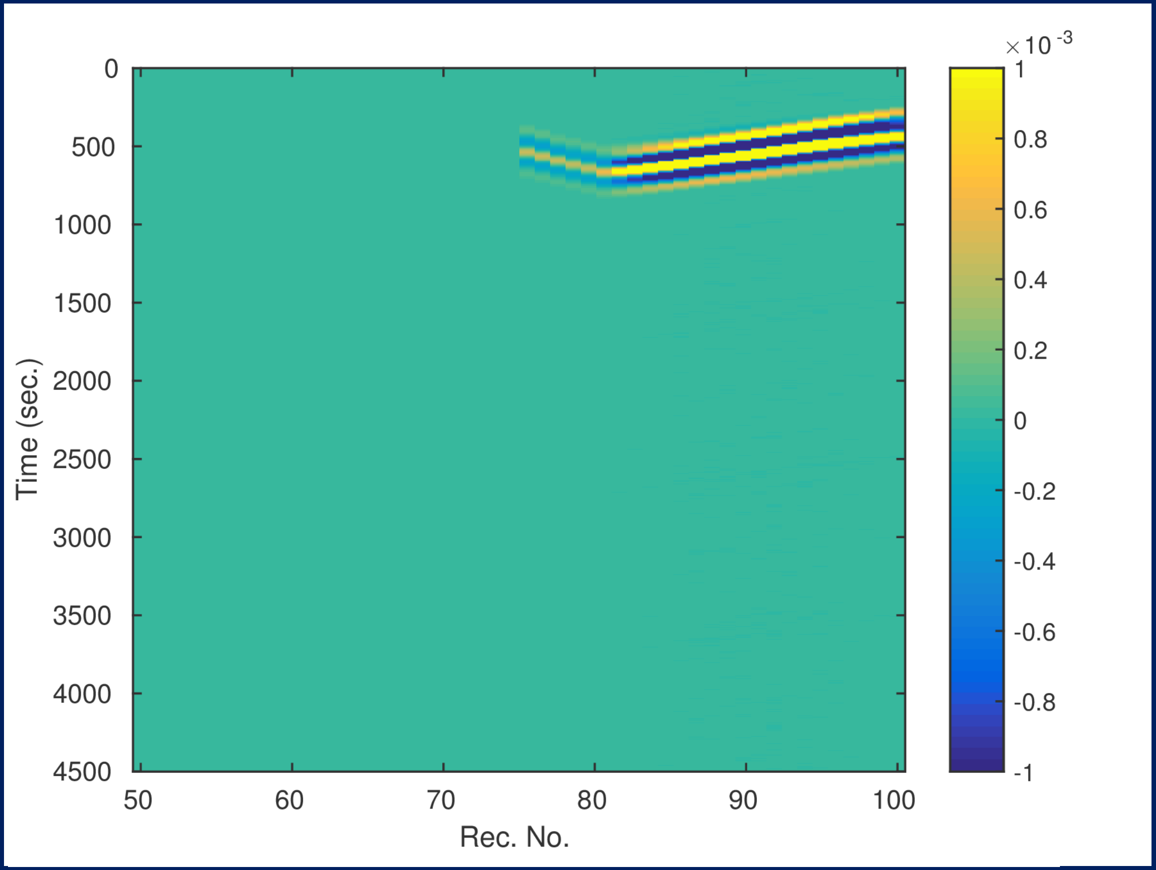
Refractions only from Virtual data



Synthetic Data Trial

Tilted Fault Example

3. Correlate the recorded (observed) and virtual traces to give the correlated data.



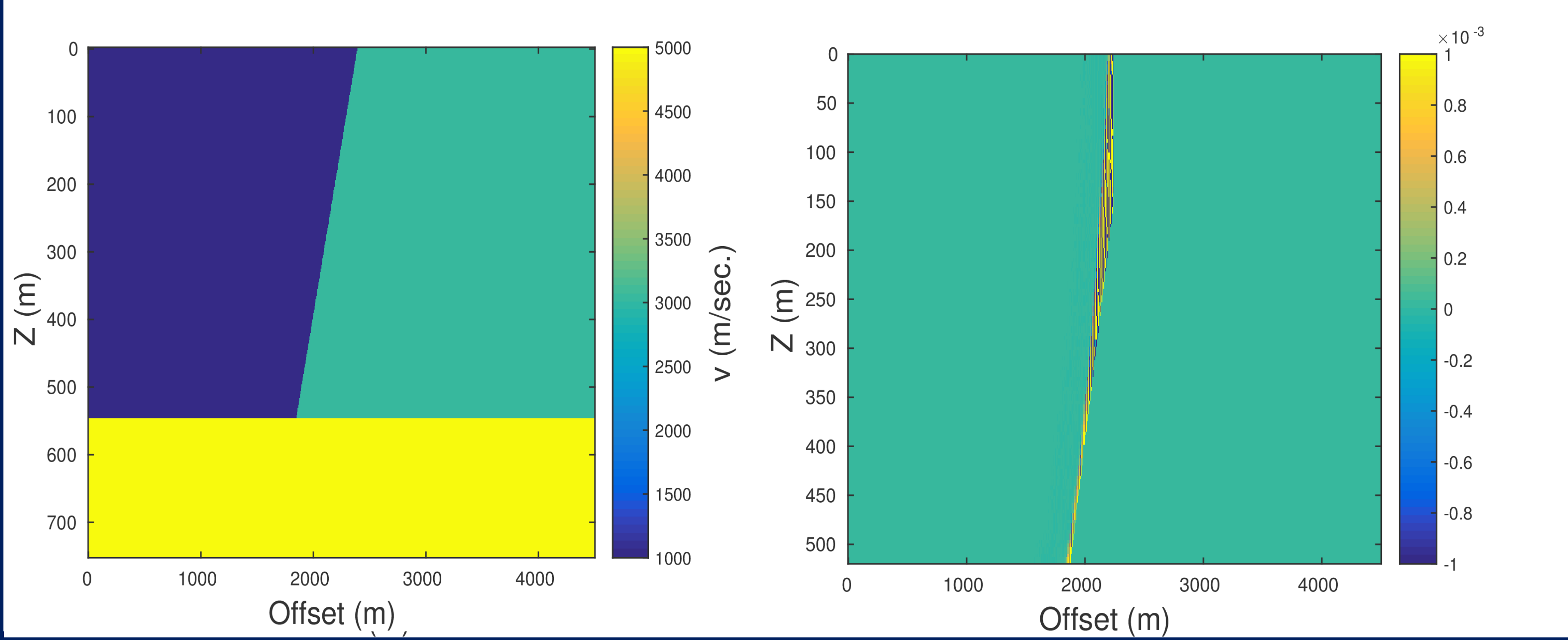
Synthetic Data Trial

Tilted Fault Example

4. Apply the migration kernel to the cross correlated data.

True velocity model

Migration image for the fault



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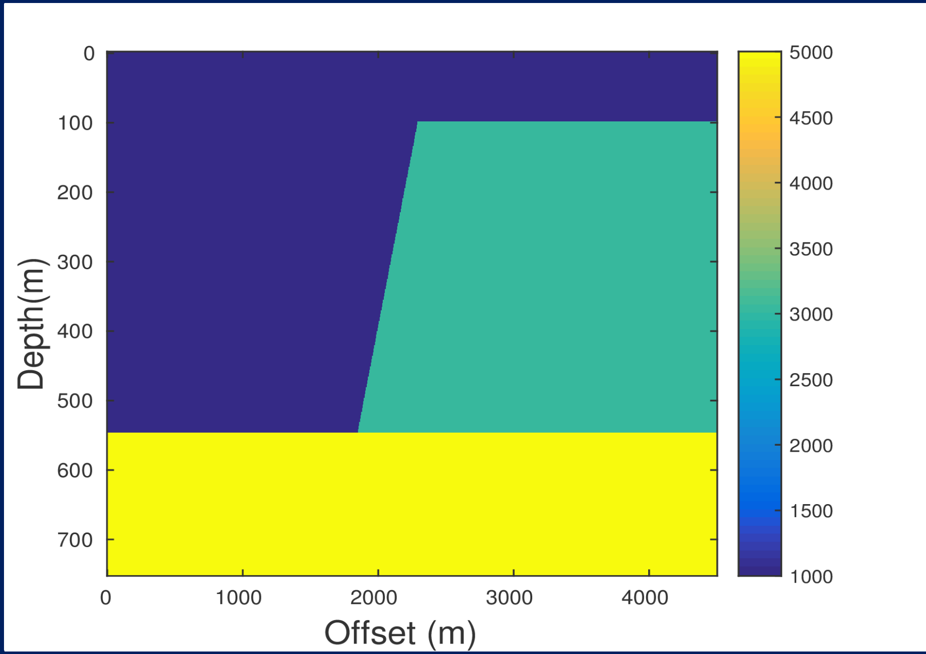
Synthetic Data Trial

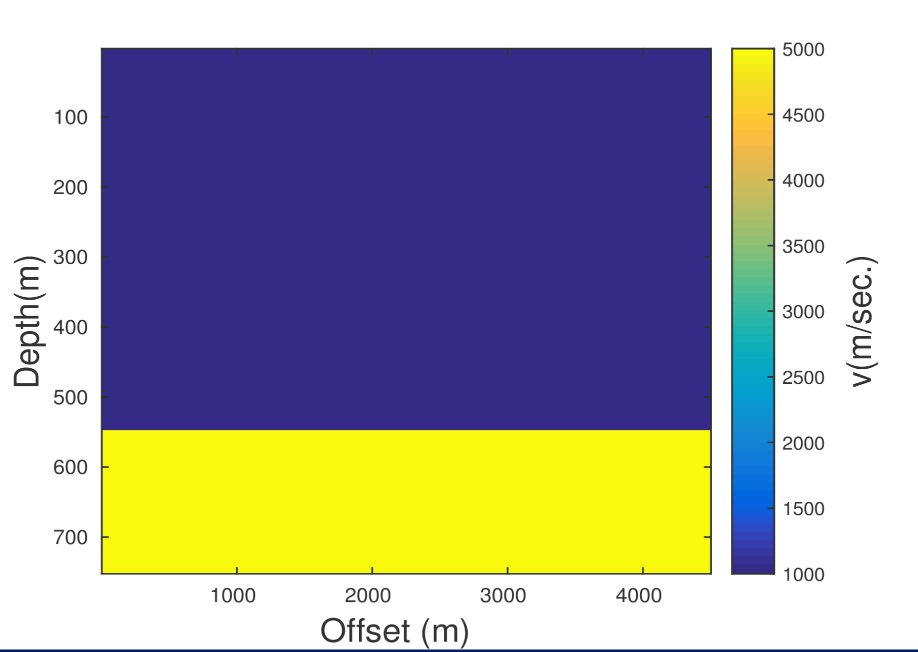
Tilted Fault Example

1. Generate the synthetic data from the true velocity model and the 'fault flooded' virtual velocity model.

True velocity model



Virtual velocity model

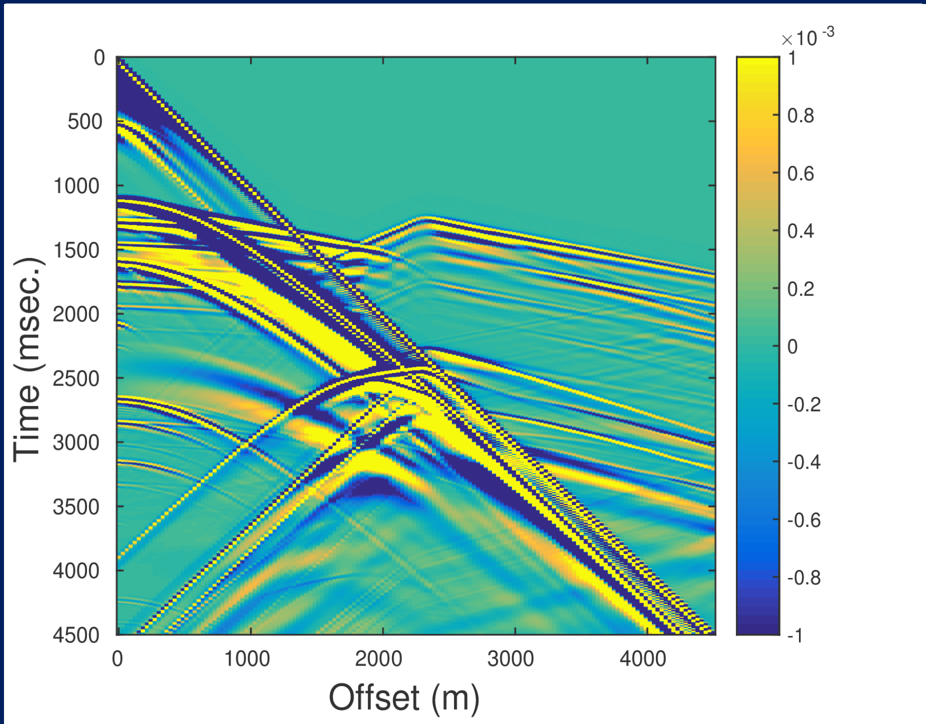


Synthetic Data Trial

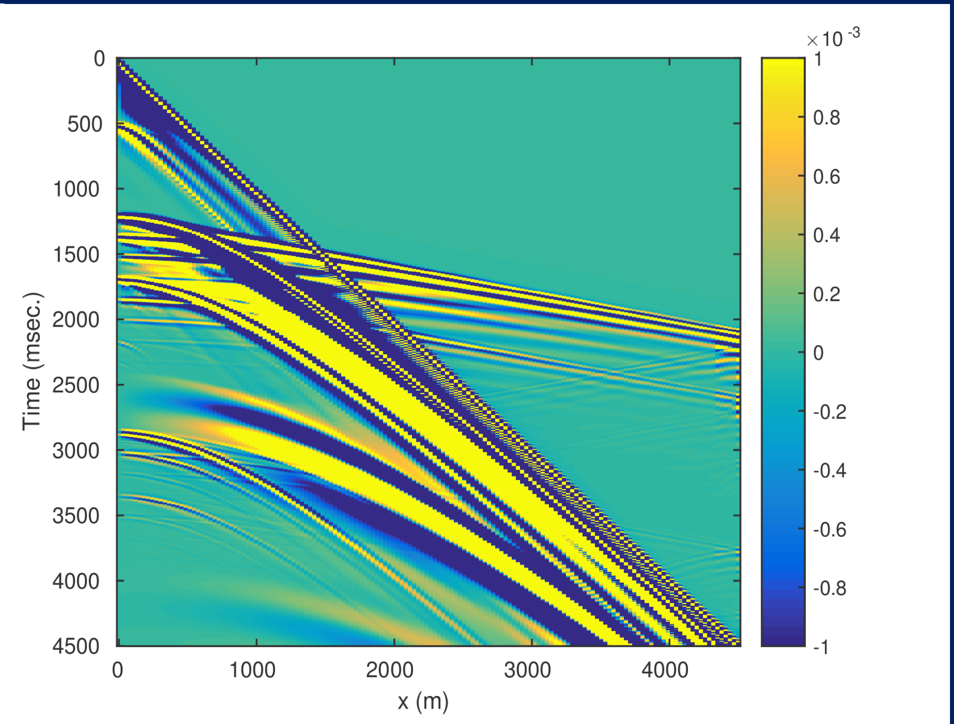
Tilted Fault Example

2. Identify and isolate the refraction events in the datasets.

Observed data



Virtual data

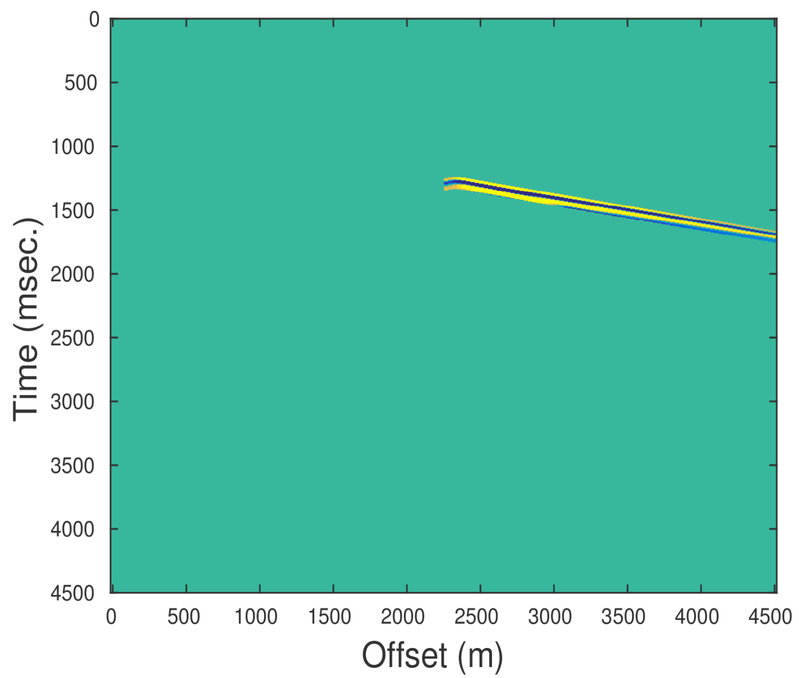


Synthetic Data Trial

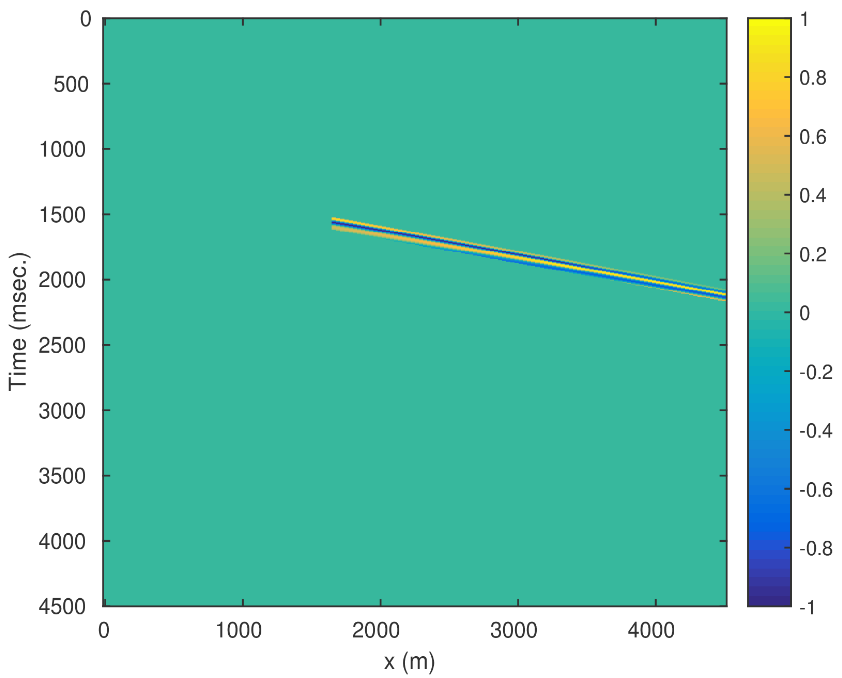
Tilted Fault Example

2. Identify and isolate the refraction events in the datasets.

Refractions only from observed data



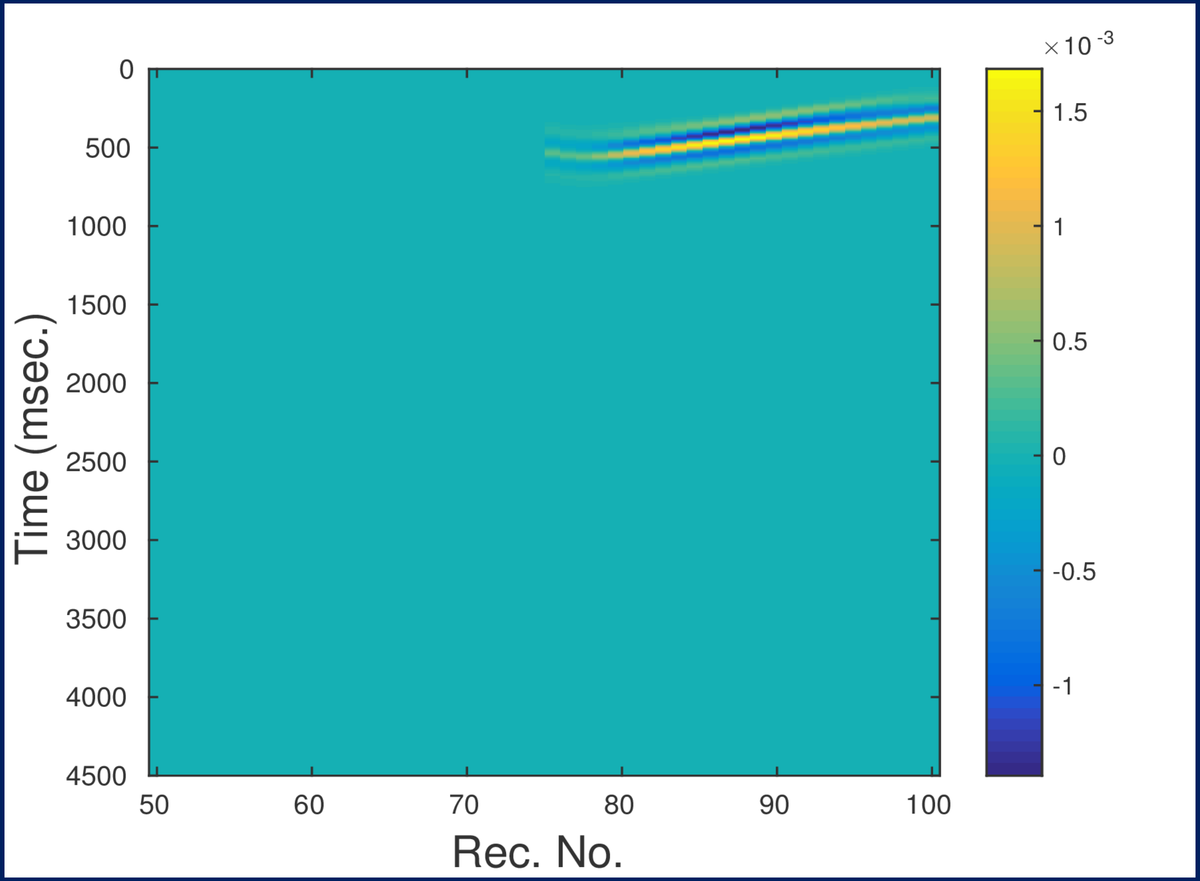
Refractions only from Virtual data



Synthetic Data Trial

Tilted Fault Example

3. Correlate the recorded (observed) and virtual traces to give the correlated data.



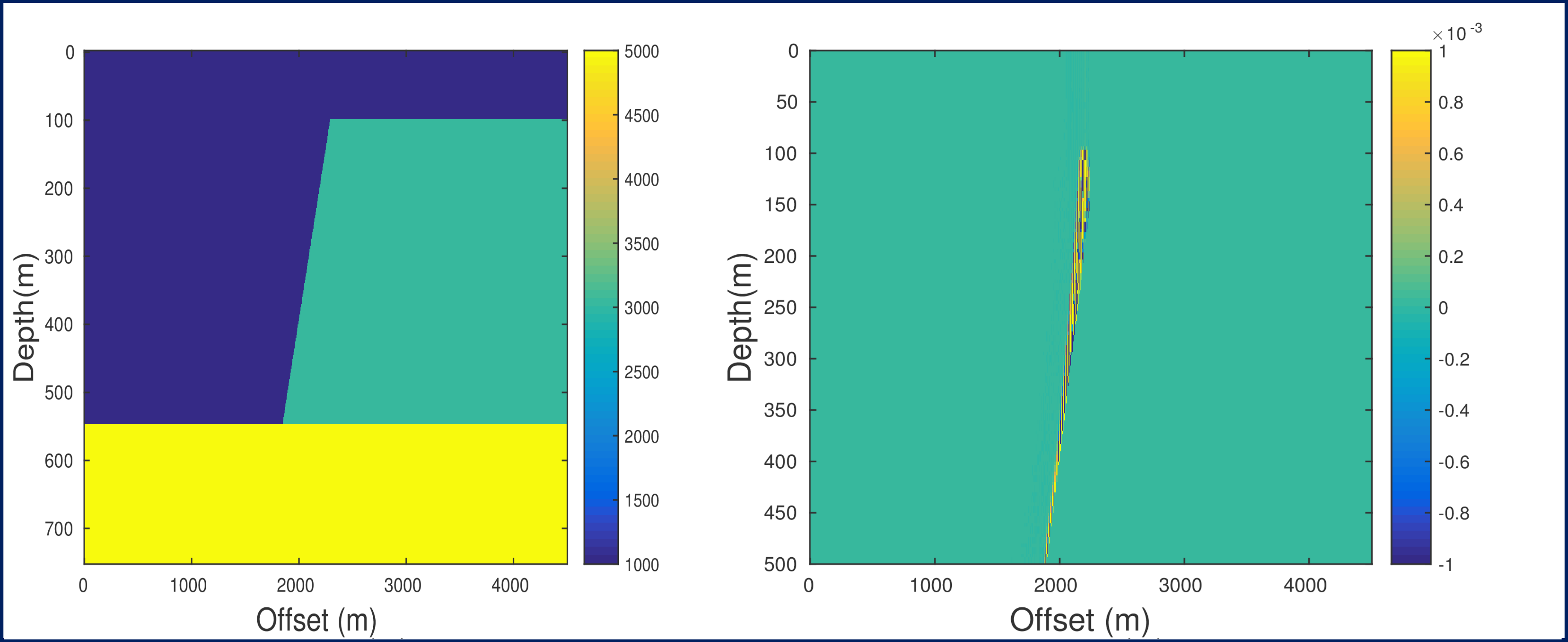
Synthetic Data Trial

Tilted Fault Example

4. Apply the migration kernel to the cross correlated data.

True velocity model

Migration image for the fault



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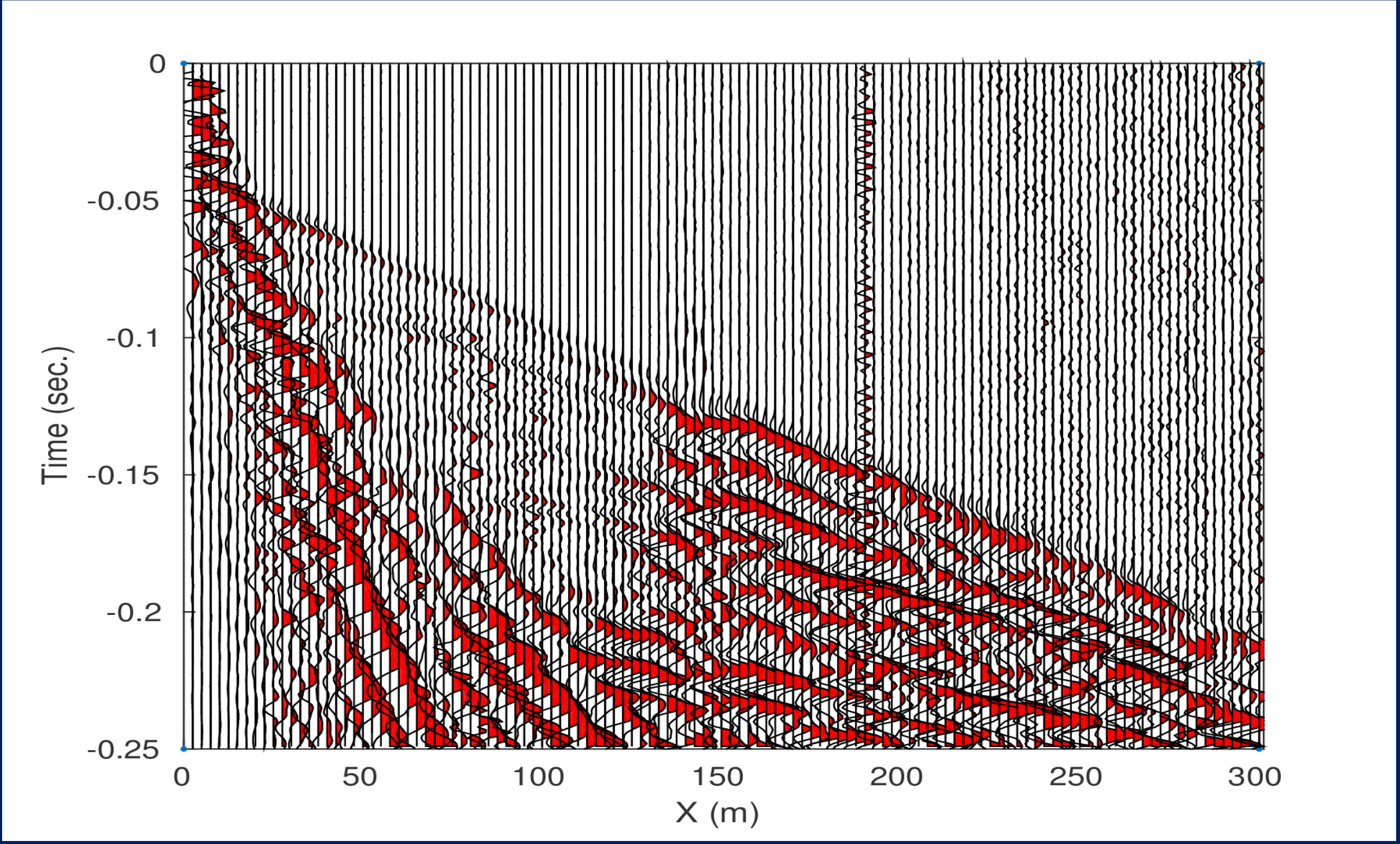
Gulf of Aqaba Field Data

1. Manipulate real data to give the virtual refraction arrivals

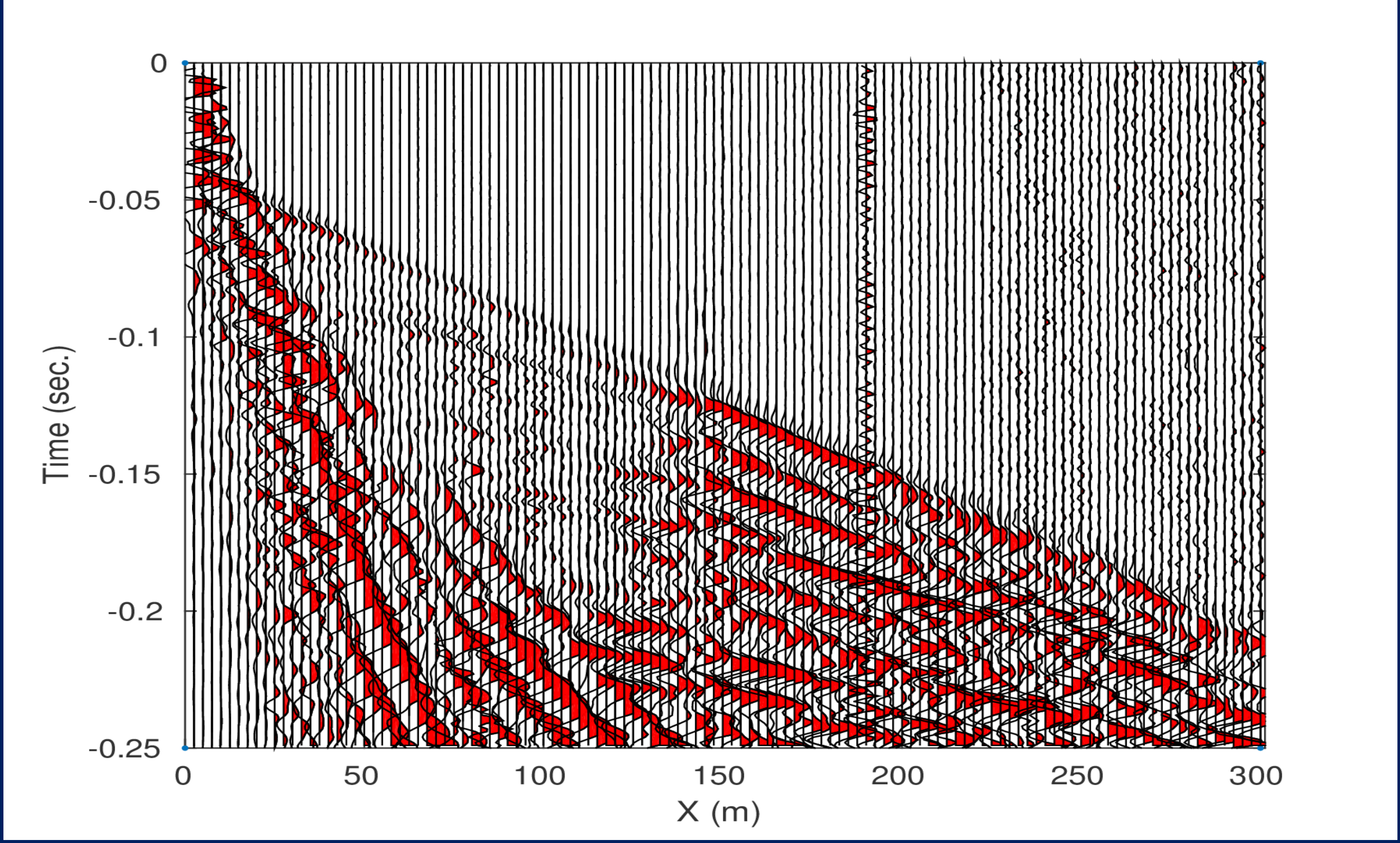
Recorded data from the field



Gulf of Aqaba Field Data

1. Manipulate real data to give the virtual refraction arrivals

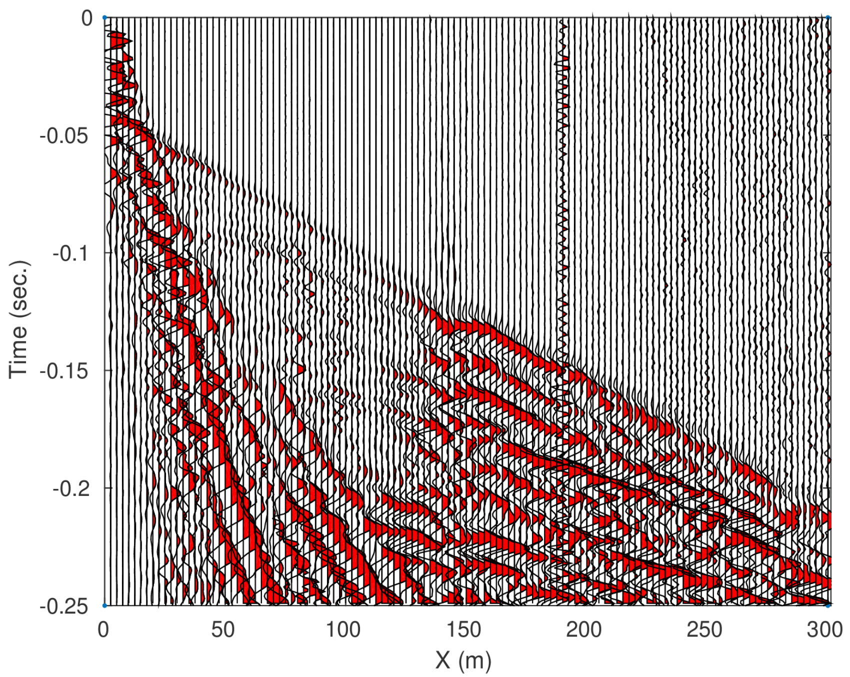
Virtual Data from Shifting Events

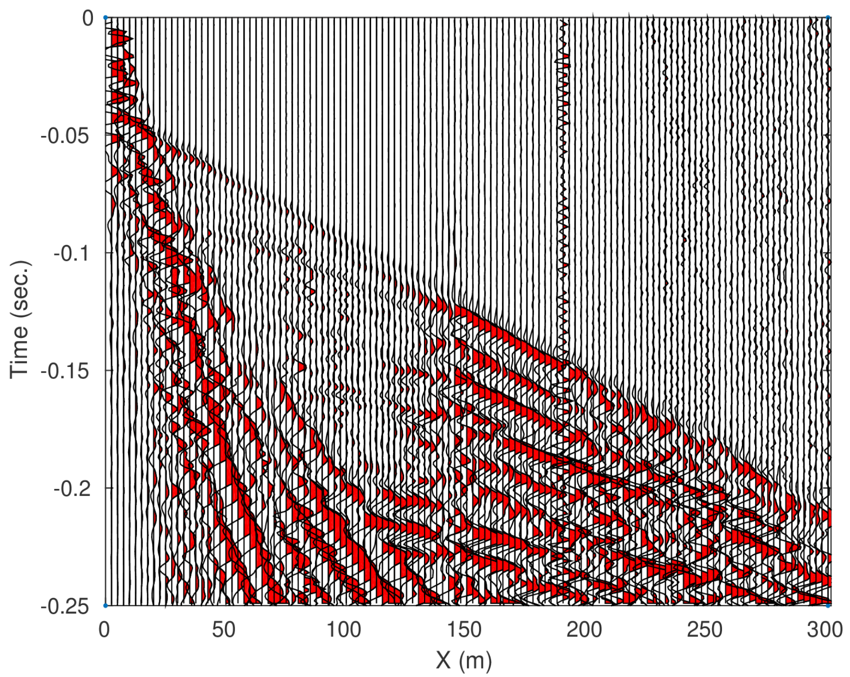


Gulf of Aqaba Field Data

2. Identify and isolate the refraction events.

Observed data **Virtual data**



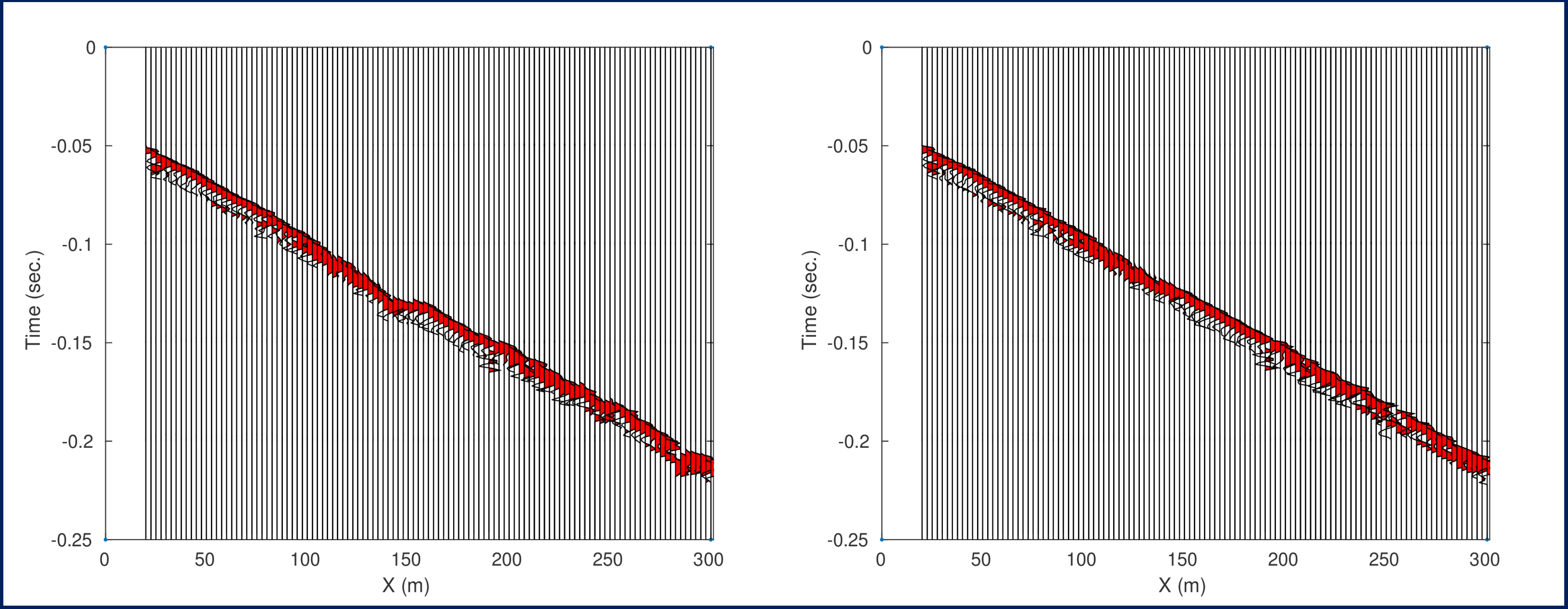


Gulf of Aqaba Field Data

2. Identify and isolate the refraction events.

Refractions from Observed Data

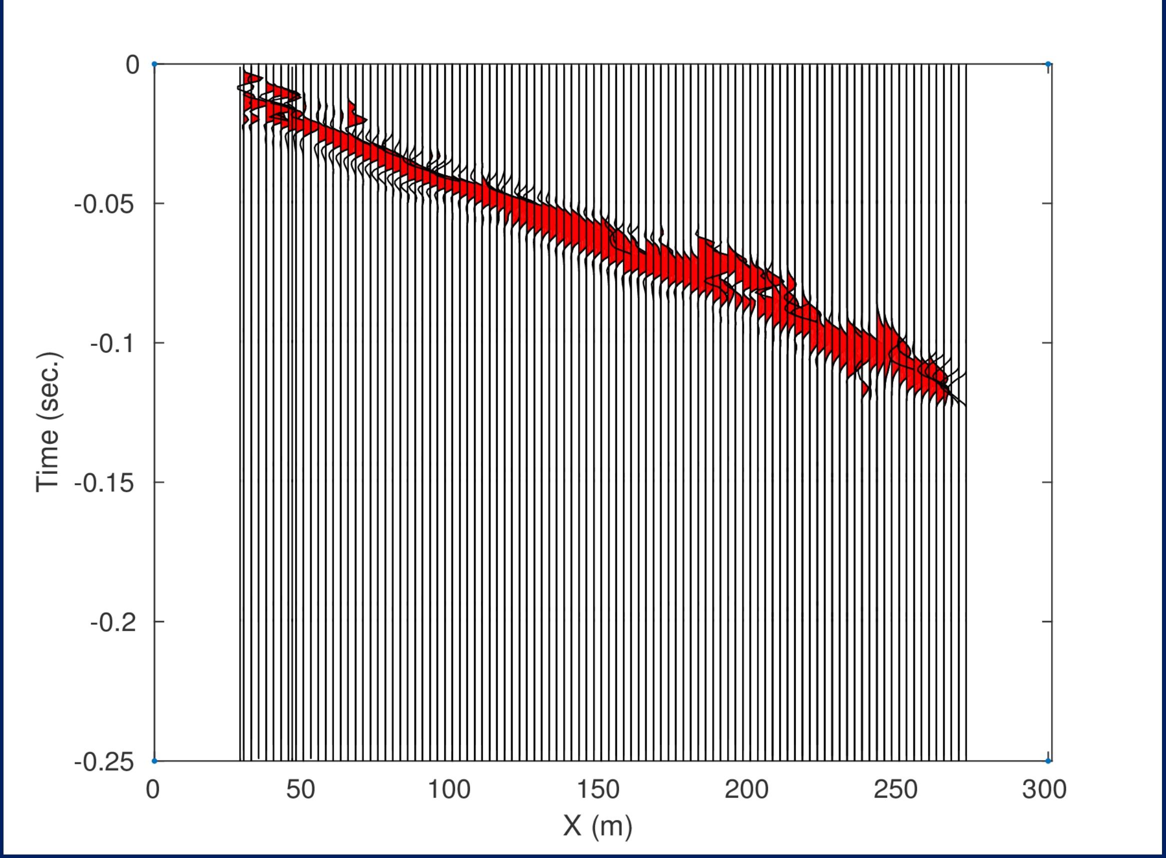
Refractions from Virtual data



Gulf of Aqaba Field Data

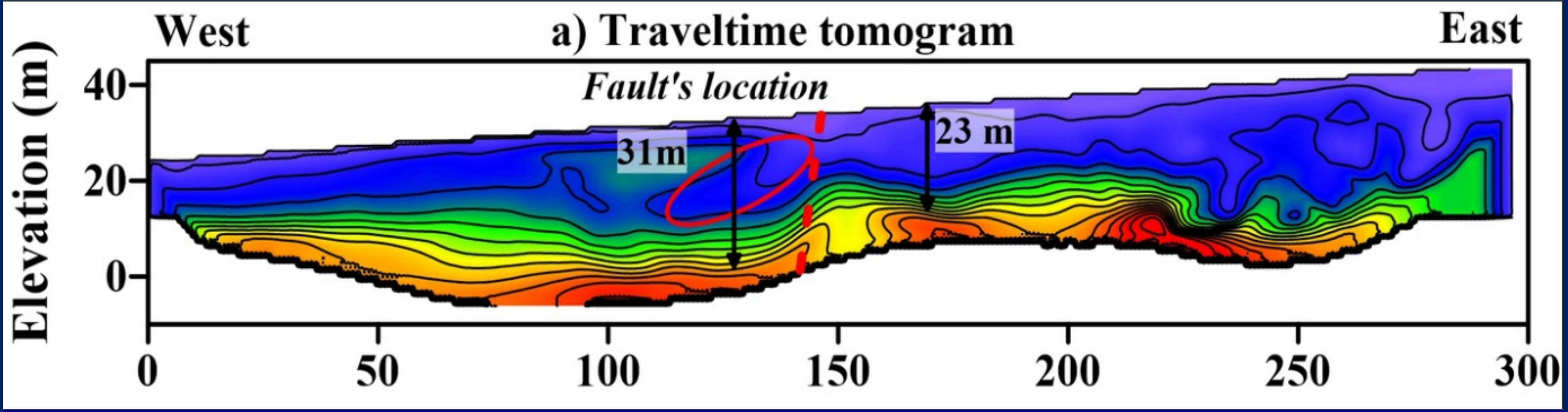
3. Correlate the recorded (observed) and virtual traces to give the correlated data.

Cross Correlated data

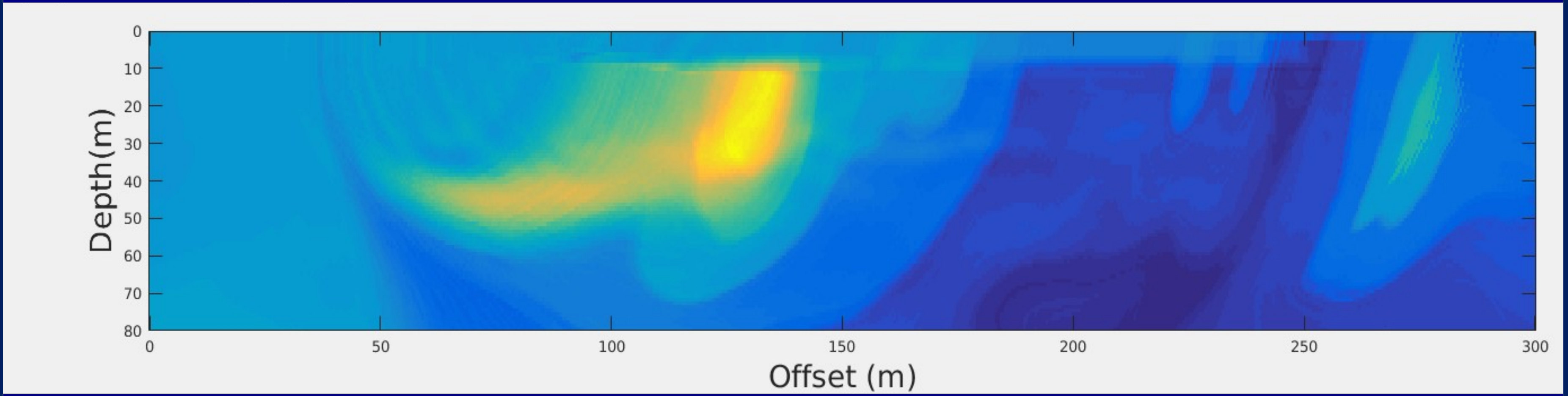


Gulf of Aqaba Field Data

4. Apply the migration kernel.



True velocity model



Migration image for the fault

Gulf of Aqaba Field Data

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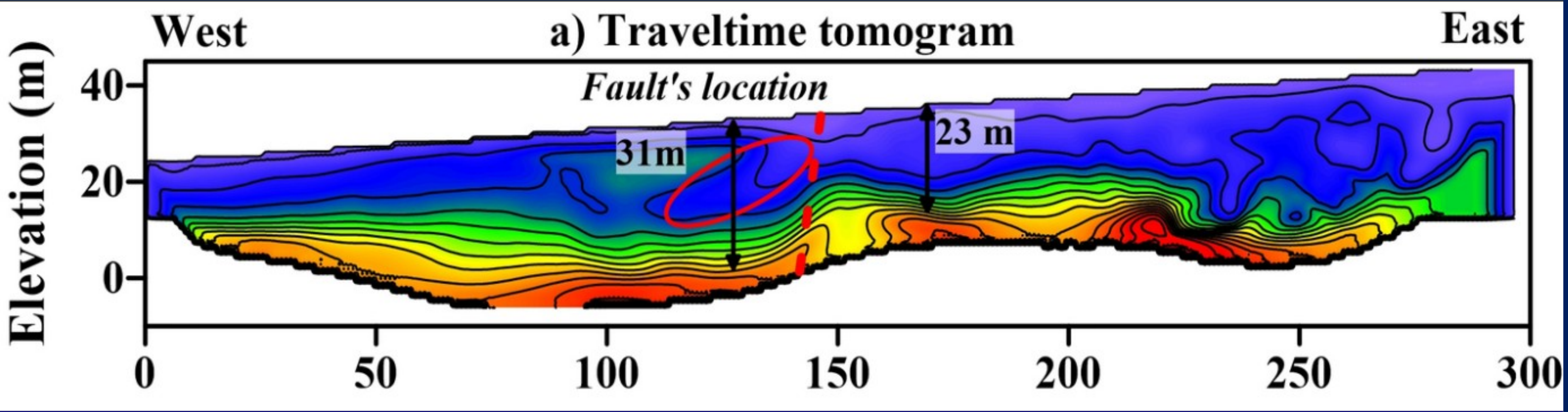
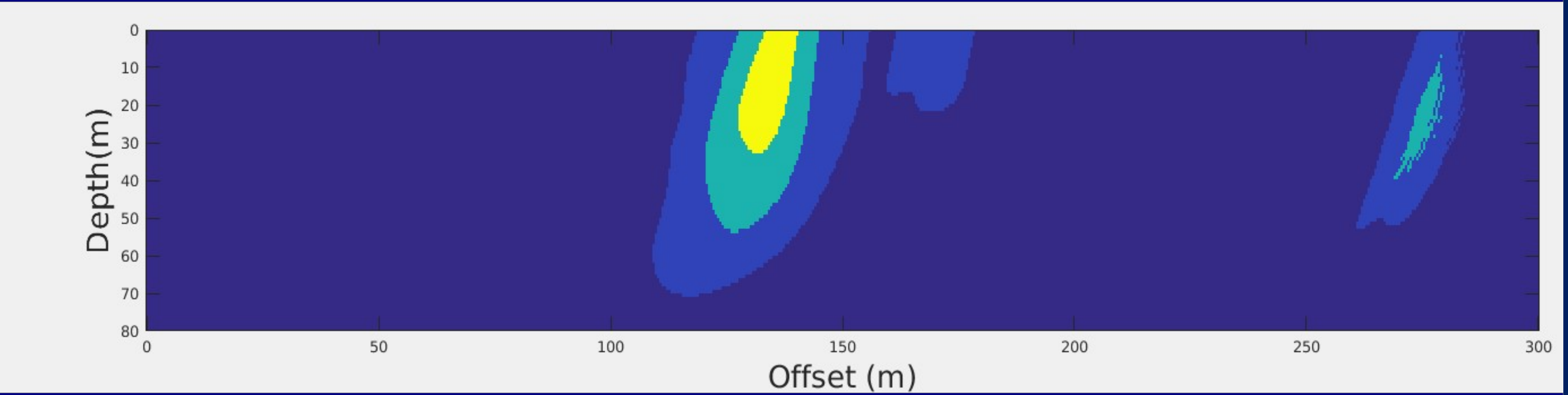


True velocity model



Migration image for the fault

Limitations

- Need strong velocity contrast on either side of the fault scarp, strike slip faults could not be accurately imaged.

- Possible to misidentify incoming refractions from deeper layers as faulting events.

Conclusions

- The fault flooding method offers a new tool in analyzing the extents of near surface faults.

- Overcomes traditional weaknesses inherent in seismic imaging with imaging steeply dipping events.

References

- Schuster,G., 2009, Seismic Interferometry: Cambridge Press.

- Schuster,G., 2015, Imaging of Near-Surface Faults by Fault Flooding and Refraction Migration.

- Sherif M. Hanafy, SEG 2014 , Imaging Normal Faults in Alluvial Fans using Geophysical Techniques: Field Example from the Coast of Gulf of Aqaba, Saudi Arabia.

Questions ?

Thank you