Undoing wavefield interference for AVAZ measurements

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- **Introduction**
  - Measuring amplitudes of **reflections** from **anisotropic rock layers** in the earth is an important new technology for obtaining information about those rock layers, including the **orientation and intensity of fractures**. Most methods require measurements of reflection amplitudes from a set of seismic traces recorded over the anisotropic layer, distributed over a **significant range** of source-receiver **offsets** and source-receiver **azimuth directions**. Even under ideal circumstances, it can be difficult to obtain **accurate** reflection amplitude measurements, due to **interference** of other coherent events with the anisotropic reflection. We demonstrate here the use of **radial trace (RT) filtering** to largely eliminate this interference, allowing accurate measurements of reflection amplitudes.
- **The method**
  - Radial trace (RT) filtering is a technique used to **estimate and subtract** selected **coherent events** from an ensemble of seismic traces representing a wavefield. Although usually employed to attenuate source-generated coherent noise from source gathers before deconvolution, static correction, and CMP stacking, we employ the method here to remove **locally linear coherent events** from a **single** desired **reflection event**. Some of its advantages:
    - **Sensitive parameter selection** allows estimation and removal of specific events, which may be removed **one at a time**
    - The RT domain provides **spectral separation** between targeted events and reflections, ***with careful parameter selection***
    - Noise events are always **estimated and subtracted**, leaving **no 'filter artifacts'**, if parameters are carefully selected
    - Parameter choice is assisted by **visual inspection** of the wavefield at each stage
- **The data set**
  - The data presented here were acquired over a **physical model** in the CREWES physical modeling facility. They consist of a set of **trace ensembles,** each ensemble acquired along a **different azimuth** with respect to the anisotropy axis of the model.
  - Measurements of **reflection amplitude** for an **anisotropic model layer** were used by *Mahmoudian to verify **AVAZ theory**, as well as to demonstrate the use of only **PP reflection amplitudes** to obtain full elastic parameters for the anisotropic layer.
- **The model**
  - The physical model constructed for *Mahmoudian's study of AVAZ theory is depicted in Figure 1. It consists of **five layers**, of which the top and bottom layers are **water**. The central layer is the **anisotropic** one, constructed of linen layers embedded in **phenolic** resin, and it is bounded above and below by isotropic. **plexiglas**
  - Using water as the topmost layer ensured that there were **no strong surface waves generated**, but introduced a train of **'ghost' events** behind each coherent event. These ghosts add to the interference problem at the target level.
  - The upper plexiglas layer has a much lower P-wave velocity than the underlying phenolic layer, so the NMO of its reflection is much greater than that of the target phenolic layer, causing **this reflection and its ghosts** to **interfere** with the **phenolic layer reflection**. Figure 2 shows an example of a trace ensemble recorded over the model in a direction parallel to the symmetry axis of the **phenolic layer** (zero degree azimuth)

*Mahmoudian, F., 2013, Physical modeling and analysis of seismic data from a simulated fractured medium, PhD. Thesis, University of Calgary

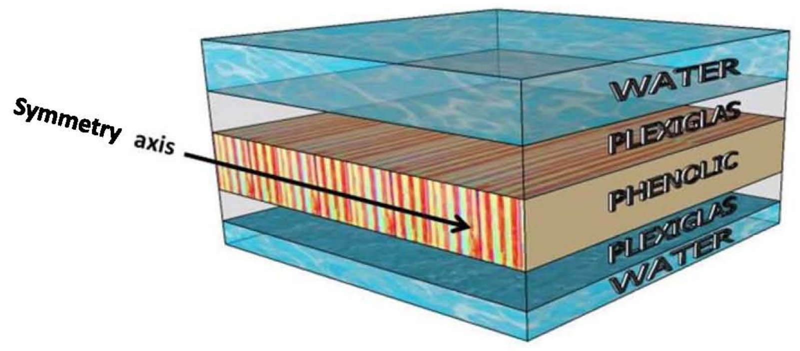

FIG. 1. The physical model surveyed at the CREWES physical modeling facility. Multiple source ensembles were recorded along **different azimuth directions** relative to the symmetry axis to provide the data for *Mahmoudian's AVAZ study.

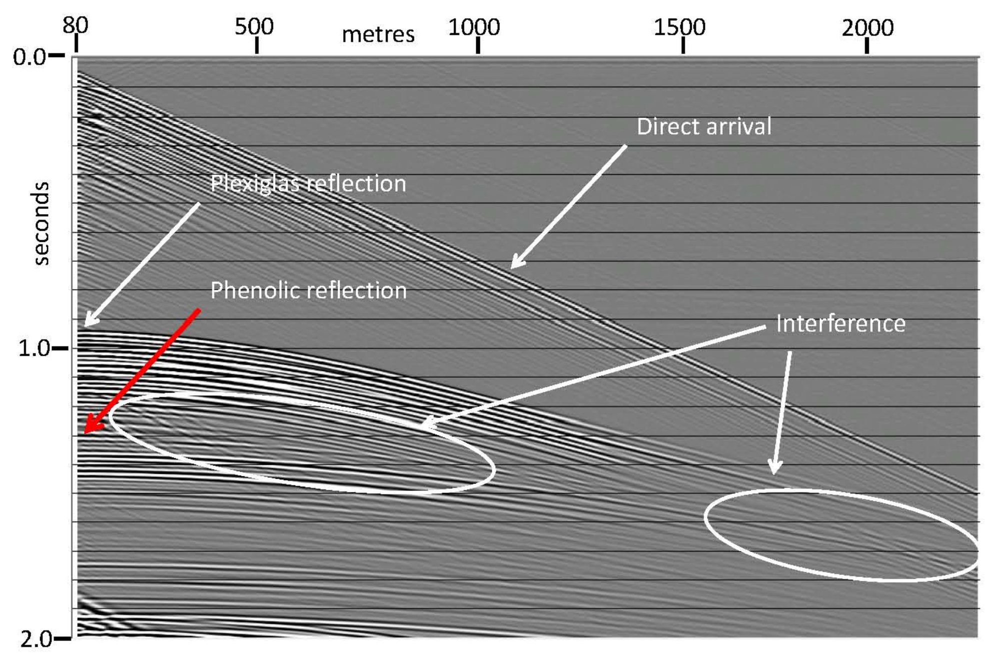

FIG. 2. The raw trace ensemble recorded along the **zero degree** azimuth on the physical model in Figure 1. The target **phenolic reflection** is marked in red. Particular zones of serious interference with this reflection are marked.

- **The problem and its solution**
  - Figure 3 shows a zoom of the target **phenolic reflection** in Figure 2, after removal of NMO. The interference of locally linear wavefronts from the direct arrival and the shallower plexiglas reflection are evident. The plot of amplitudes picked along the peak of the phenolic reflection shows that ***these measurements are useless for verification of theory***.

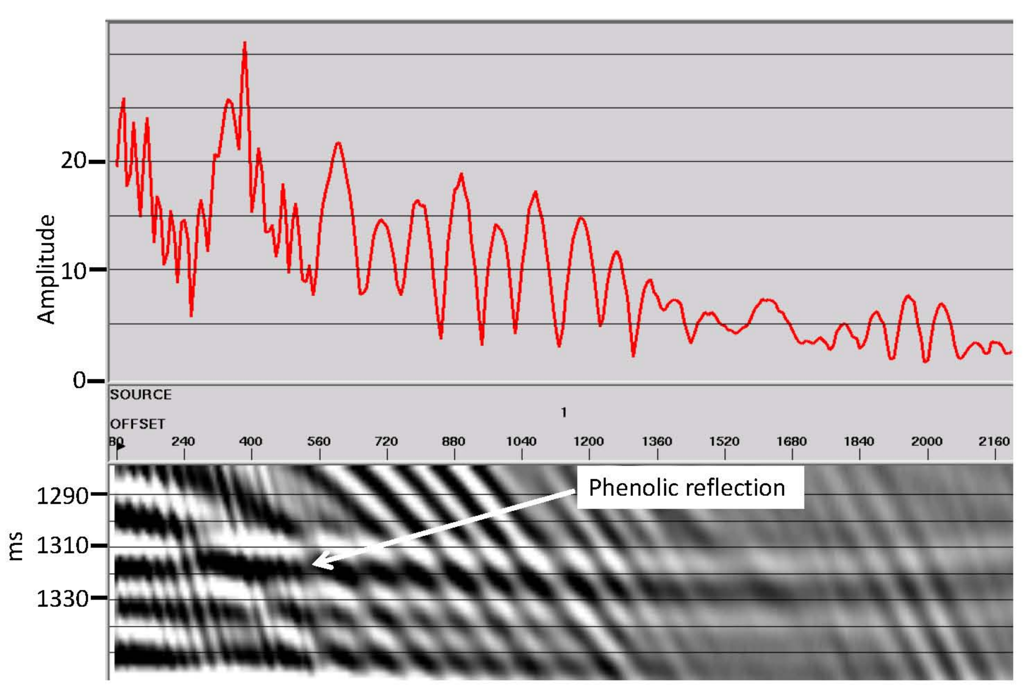

FIG. 3. Zoom of the phenolic reflection event in Figure 2, with NMO removed. Wavefield interference makes amplitude measurements essentially meaningless.

  - Figure 4 shows the same **phenolic reflection** after application of a series of RT filters, each aimed at a coherent event of a specific slope in Figure 3. ***The picked amplitudes are now consistent enough to use***.

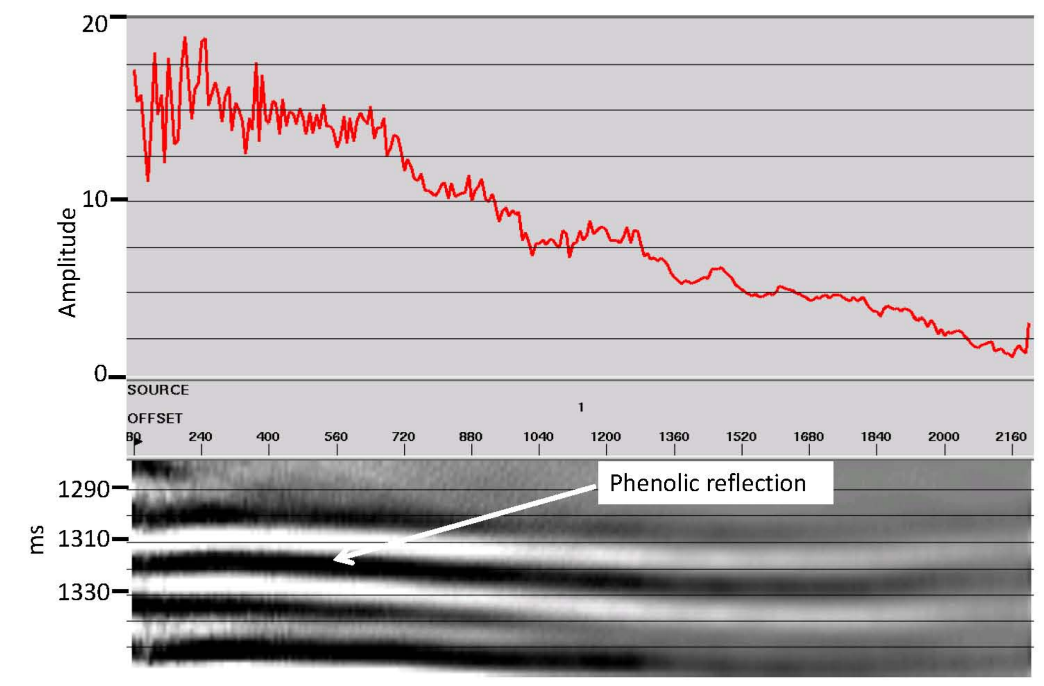

FIG. 4. Flattened **phenolic reflection** after removal of nearly all linear interfering events. Amplitudes are now clearly more usable.

- **More examples**

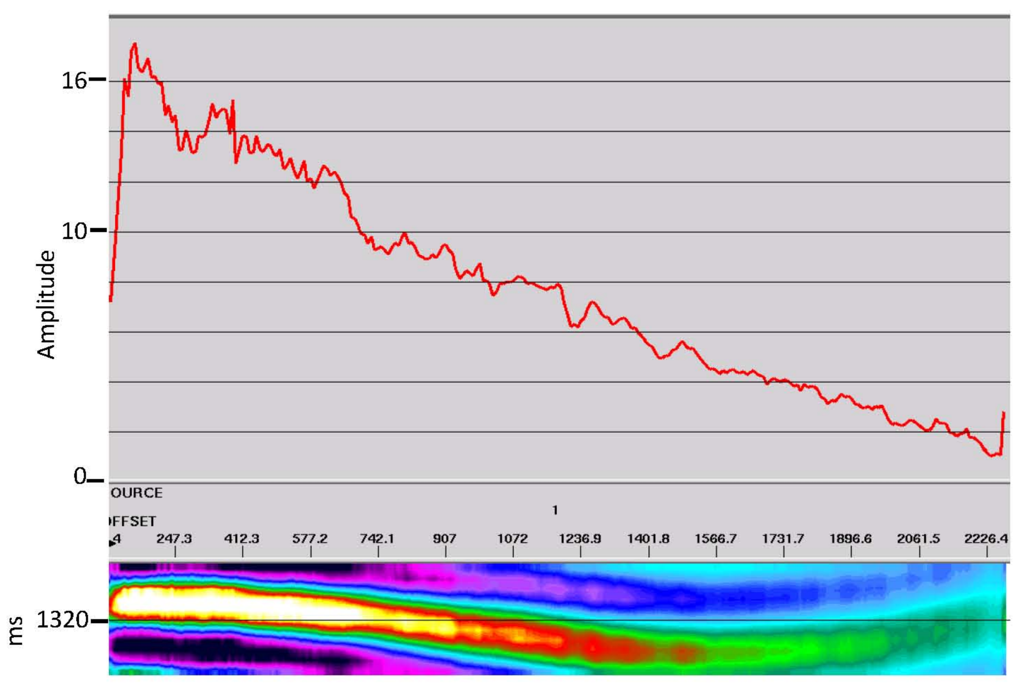

FIG. 5. **Phenolic reflection** at an azimuth of **14 degrees**, after removal of wavefield interference.

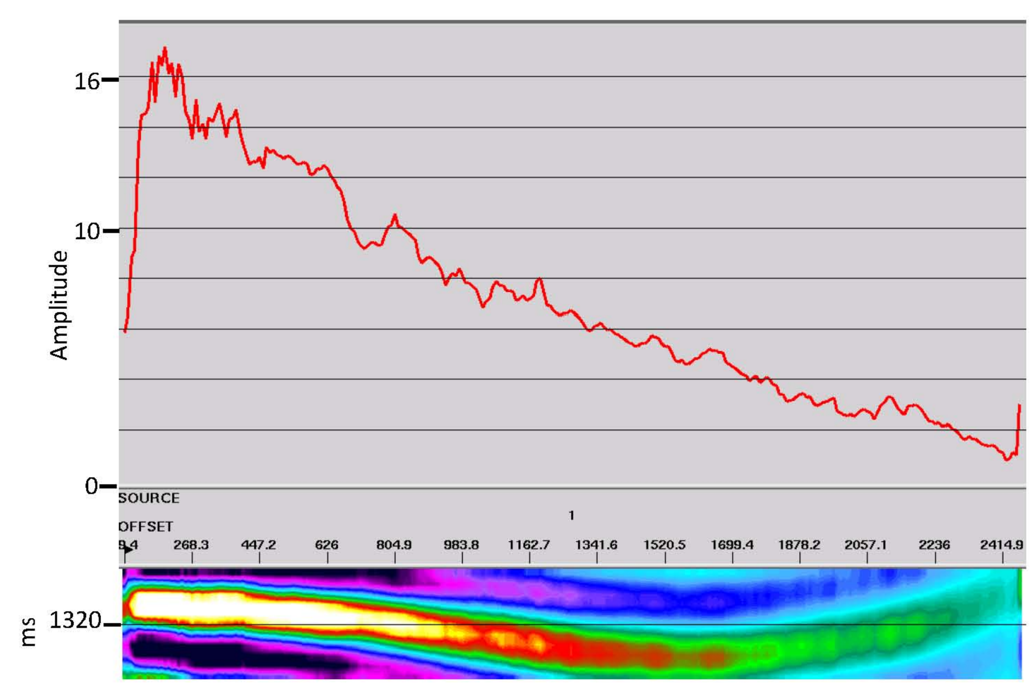

FIG. 6. **Phenolic reflection** at an azimuth of **27 degrees**, after removal of wavefield interference.