Where are the reflections hiding in single-sensor land data?

Andrey Bakulin, Ilya Silvestrov, EXPEC Advanced Research Center, Saudi Aramco, Dmitry Neklyudov, IPGG, Novosibirsk

Seismic acquisition continues to evolve towards smaller field arrays and single sensors. In geological environment with complex near surface, reflection signals become mutilated and covered with thick trains of scattered noise. Figure 1c shows typical single-sensor record after conventional pre-processing. It is clear that conventional ways of finding weak signals are not working.

- Does it make geophysical sense to acquire such data?
- Can such small and broken signals ever be recovered and processed?
- Can we ever trust the amplitudes of such data?
- Can such data deliver better reservoir inversion than previous generation of data with larger arrays?

These are all pressing questions that acquisition and processing community need to resolve in order to convince interpreters and engineers to continue investing in next generation of seismic data. If we would be able to acquire single-sensor data with super-dense sampling of 5x5 m – we would likely solve this problem like before, but can we solve it now when sensor/source spacing remains still relatively large to sample near-surface noises appropriately?

In order to deal with this problem, we need to gain deep fundamental understanding how single-sensor records are distorted. Figure 1a shows shot gather computed in a land model with heterogeneous near surface. While it is reasonably distorted – we still observe very clear events processable by conventional methods. We conclude that by itself this mechanism does not capture full extent of signal mutilation seen on real data (Figure 1d). Figure 1b shows same gather after novel distortion modeling approach that is much more closely resembles field data. Once we understand nature of these damaging distortions, we can find a way to mitigate them at least to a large extent. Figure 1c shows nonlinear beamforming (Bakulin et al., 2018) applied on this gather that is able to re-assemble reflection signals in a meaningful way. Figure 1d shows application of nonlinear beamforming to real data in cross-spread domain. Similar to synthetic, we can find the signal if we understand how it was damaged and utilize full power of multi-channel data to recover it. Restored signal may not be perfect and some small details could be lost (compare 1a and 1c), but on real data we can achieve a major breakthrough (compare 1d after conventional processing and 1e after beamforming). There are additional approaches that could emerge to recover more details. More important question is to understand if these details are associated with the reservoir or near surface issues and acquisition imperfections? If the latter, then we may only want to recover reliable parts associated with the reservoir and leave out the distortions. New understanding opens number of avenues to address these questions in a meaningful way. Most importantly, we could immediately improve processing of difficult data currently acquired with small arrays and single sensors.

In summary, we have reached fundamental new understanding of signal distortions on single-sensor data. Armed with this knowledge we are able to recover main part of the reflected signals using innovative approaches based on local beamforming. These findings are critical both for processing and acquisition design in areas with complex near surface.

References

Bakulin, Silvestrov, I., Dmitriev, M., Neklyudov, D., Protasov, M., and K. Gadylshin, 2018, Nonlinear beamforming for enhancing prestack seismic data with a challenging near surface or overburden: First Break, 36 (12), 121-126.

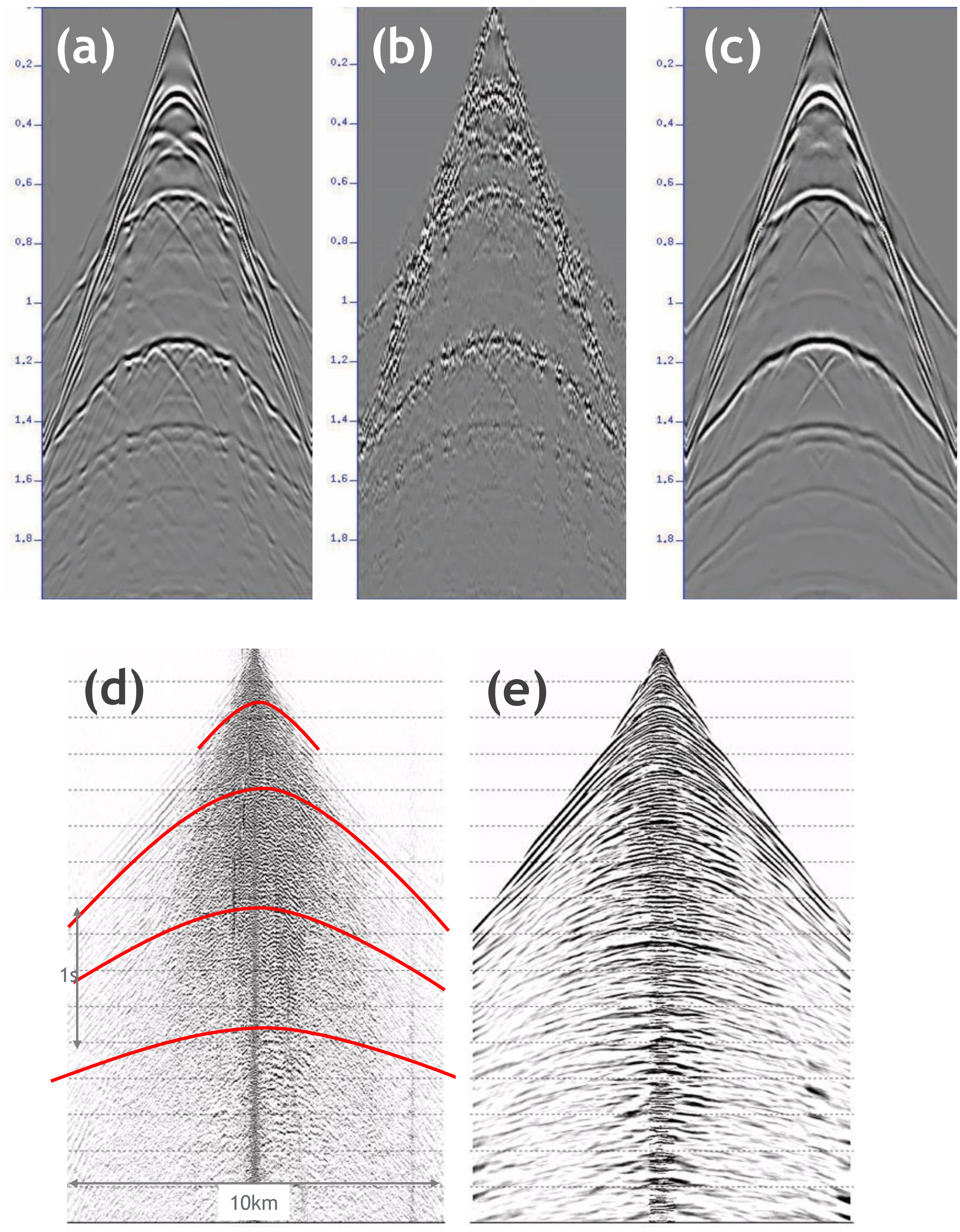

Figure 1. Synthetic gather in a model with complex clutter-like near-surface (a) was subject to realistic distortion modeling (b) replicating more closely real single-sensor data (d). After nonlinear beamforming, we are able to reliably recover largest part of reflection signals (c). Panel (e) shows application of nonlinear beamforming to real land single-sensor data from (d). Observe reliable recovery of reflection signal that is hidden after conventional single-sensor processing already performed on (d).