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Thrust Belt Imaging Challenges – Learning from 3D Fullwave Modeling

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SUMMARY

Seismic image quality in foothills and thrust-belts with rugged topography is often very poor with conventional low-fold sparse 3D orthogonal surveys. The most often cited reason is the high-level of shot-generated noise backscattered from near-surface heterogeneities and irregular topography. Consequently, many depth imaging projects in thrusted terrains have been disappointing.

The principal motivation for this study is to assess in a systematic and quantitative way the challenges raised by the conventional acquisition-to-imaging workflow in foothills exploration context. Specifically, here we investigate the impact of the sparse and highly irregular seismic acquisition geometry in mountainous terrains with difficult access and rough topography. Using proprietary 3-D full-wave modeling that handles irregular topography we analyze both homogeneous and heterogeneous near-surface velocity models with the same background reflectivity. We then evaluate the impact of sparse 3D orthogonal surveys on image quality when using the exact velocity model and accurate imaging algorithms.

We show that in absence of near-surface heterogeneities but rugged topography, the sparse 3D orthogonal geometries may image correctly only the deeply buried targets. In the real world, however, we often have a very heterogeneous near-mid subsurface with short-wavelength (relative to receiver spread-length) velocity perturbations and thickness variation. This generates significant amount of reverberated body-wave refracted energy, which is subsequently scattered by the rugged topography and occurs as fuzzy “noise” throughout the entire shot record. Then, we explore the intimate relationship between the high-order scattered energy and its coarse spatial sampling with conventional low-fold sparse 3D acquisition geometries usually employed by the industry in such terrains where difficult access, cost-efficiency and field effort are major concerns. In these particular settings, this scattered primary energy is spatially aliased in all domains, acting as very energetic signal-generated “noise” difficult to handle with conventional pre-processing. As a result, we prove that static corrections and even the most advanced imaging algorithms such as Reverse Time Migration (RTM) and Beam, will likely fail to yield interpretable images of the subsurface even when the near-surface/background velocity model is known.

We conclude by emphasizing that in foothills, the compromises made in field-effort and economics should always be governed by the near-surface heterogeneity and the resulting level of noise, more than the background model regardless of its structural complexity. Learning from model-based 3D acoustic and elastic full-wave modeling and depth imaging is the key towards cost-efficient and fit-to-purpose survey evaluation and design where CMP-fold rule-of-thumb and ray-based modeling are no longer appropriate.