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Active source surface seismic imaging; evolution of technology and choices

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Active source surface seismic surveys constitute one of the fundamental datasets for hydrocarbon exploration, development and production. Advances in acquisition and computing hardware continue to enhance the base seismic image quality. However, it is a fairly simple exercise to demonstrate that when employing common seismic processing workflows, conventional survey designs 1) severely under-sample the near surface (by a factor of $\sim 10^6$); and 2) in the presence of complex structure, insufficiently illuminate (by a factor of $\sim 10^2$) the deeper subsurface. In addition, major projects require large financial commitments; easily reaching $100M's for major 3D seismic projects. Therefore, real choices need to be made in the total geophysics workflow with regard to where significant improvements in the seismic image can be achieved. As the options increase, the choices made become more dependent upon the specific imaging objective. Improvements in available channel count, combined with the capability to record multi-component data, allow for "field-oriented" improvements to the subsurface illumination and sampling issues, and for the potential to image "invisible" reservoirs from shear/converted shear wave data. However, "field oriented" approaches are generally the most costly option and, on their own, insufficient. Other options include application of emerging algorithms which include wavefield physics (1C and 3C) and sparsity theory for mitigation of surface waves, multiples and sampling deficiencies. Similarly, availability of low-cost, high performance computing allows for the inclusion of more complete physics in the seismic imaging algorithms. This has enabled the evolution of the imaging "base standard" from Kirchhoff, to one-way wave equation to, in the near future, reverse time migration algorithms. However,

including effects such as anisotropy, Q, and illumination correction into an efficient imaging algorithm often provides higher value than using more compute-intensive algorithms which do not accommodate these phenomena. Similarly, realizing enhanced seismic images thru more exact migration algorithms is still very dependent upon the quality of the velocity model (which represents a somewhat circular problem). An alternative, which is clearly the long term challenge, is “full wavefield inversion”, where the objective of seismic imaging is not in the production of seismic trace data, but in the output of a seismic-based estimation of the subsurface velocity and density fields.

In this paper we show examples where we have achieved significant improvements in the final seismic images through selective application of problem-specific technologies.