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Choosing the Right Seismic Acquisition Geometry for Your Survey: Line Intervals & Distribution Comparison

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Summary

Seismic acquisition geometries, which determine the distribution and location of sources and receivers, are typically selected based on a balance between the subsurface imaging requirements and the field acquisition costs. The optimal survey for a specific area is target dependent and will include cost considerations such as terrain constraints, source type, and equipment deployment. Here, we will only focus on how different geometries impact subsurface imaging. This is important because the most expensive seismic survey to acquire is one that doesn't meet its subsurface imaging objectives.

Theory

A seismic acquisition geometry can be defined by three factors: the source and receiver station intervals, the source and receiver line intervals, and the inline and crossline offsets of the recording script (i.e., which receivers are actively recording for each source) (Fig. 1). The station intervals help determine the resolution of the data (maximum unaliased frequency) with the natural bin size of the data equal to half the station intervals. The line intervals impact the signal-to-noise with larger line intervals having lower fold and trace density when comparing geometries with the same station intervals. Line intervals also have an impact on the bin-to-bin offset and azimuth distribution, which is important to consider when designing for pre-stack processing and inversion. The inline and crossline dimensions of the recording patch also help determine the fold and trace density as well as the azimuth and offset distribution within the data. However, for shallow targets, these parameters should also be examined from a processing requirement perspective. For example, to ensure adequate offsets for refraction statics. Additionally, the distribution of near vs. far offsets and the bin-to-bin variation in azimuth-offset distribution can impact the effectiveness of processing algorithms such as interpolation and migration. Although Fold has traditionally been used for comparing designs, trace density (Crook, 2022; Naghizadeh et al., 2023), near vs. far offset distribution, Fresnel Fold (Naghizadeh et al., 2022; Hons, 2022), and Kx-Ky plots (Naghizadeh, 2015) can provide better metrics for accurately comparing seismic geometries.

Results

In this paper, we are focusing on differences in subsurface imaging when varying both the line interval and line distribution. To isolate these differences, all geometry comparisons have the same station intervals (bin size) and recording patch (inline and crossline offsets). In order to examine this, we have decimated a fully sampled dataset (station intervals = line intervals = 20m) into orthogonal geometries with 40m, 60m, and 80m line intervals as well as several non-orthogonal and linear type geometries (Vermeulen et al., 2022; Naghizadeh et al., 2023). The alternative geometries include slanted source lines, Mega-bin (Goodway and Ragan, 1996), slim-bin, and several EcoSeis-type geometries (Birce et al., 2023) for reduced environmental footprint.

As expected, lower trace density and large line intervals have a strong impact on the quality of the subsurface image (Fig. 2). This is easily observed when comparing time slices and Quantitative Interpretation results between a well-sampled and sparsely sampled orthogonal geometry. However, the changes in the near offset distribution and bin-to-bin offset-azimuth distribution that occurs with non-orthogonal geometries also have a strong impact on data quality. These have a direct effect on interpolation in processing and final inversion results, which is important to consider when selecting a geometry for reduced environmental impact and field efficiency. Although there are many geometry options available, the ideal geometry will be one that effectively balances the subsurface imaging requirements with acquisition costs and environmental impact.

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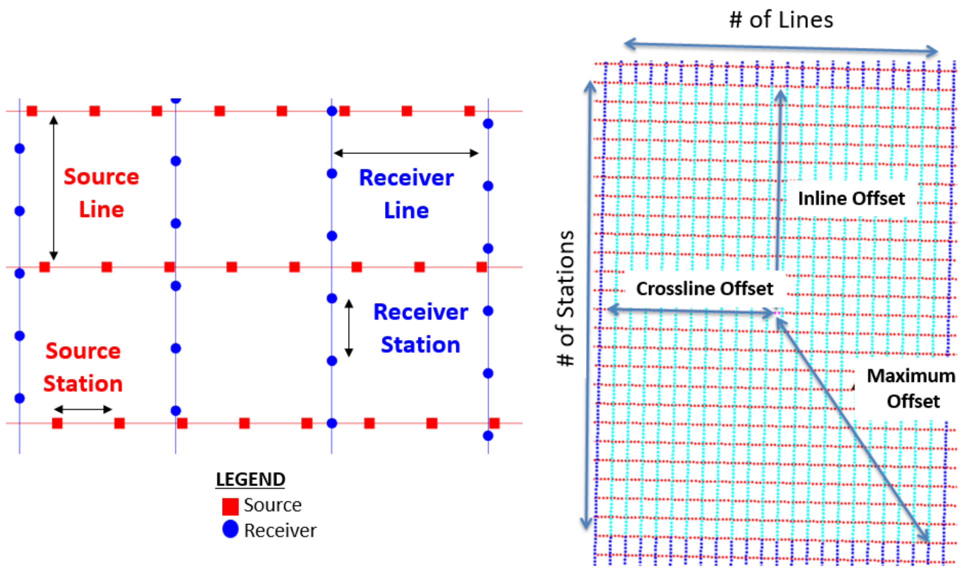

Figure 1: Geometry Definitions.

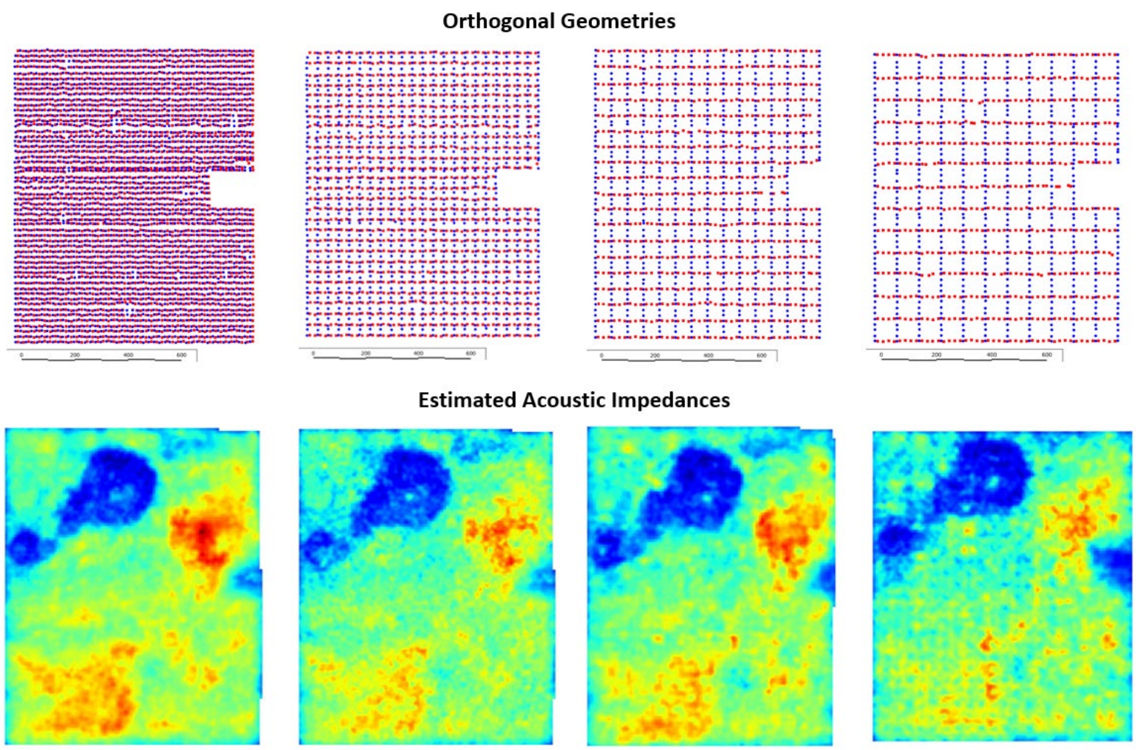

Figure 2: Comparison of Orthogonal Geometries with 20m, 40m, 60m, and 80m line intervals.