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# How to acquire seismic data with steep dips

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## Summary

There are several factors to consider when acquiring or reprocessing seismic data in an area with steeply dipping beds. Not only is it important to consider frequency aliasing at steep dips, but the dimensions of the recording patch and the overall size of the survey should also be considered. Additionally, source type and size should be examined to confirm sufficient energy will be recorded at the far offsets. In this paper, we will examine geometry selection, survey size, and seismic source parameters with regards to the imaging of steep dips.

## Introduction

All seismic survey designs should consider the frequency content and dip of target reflectors, but when targets have dips greater than 30 degrees, additional considerations need to be taken to ensure steeply dipping energy is properly sampled and recorded. The survey design needs to consider frequency aliasing with dip, the maximum offsets needed to record the dipping reflectors, the size of the migration operator, and the surface area of the survey. For complex structures with varying dips, this can be very complicated and a modeling study involving ray tracing and/or processing tests may be recommended.

## Sampling requirements for steep dips

Traditionally, the survey bin size is selected so that each dipping reflector has the maximum possible unaliased frequency before migration (Cordsen, 2000). There are various calculations for determining bin size, and although all of them consider the velocity to the target (V) and the frequency before migration (f), when designing for steeply dipping reflectors, it is critical to consider the dip of the reflector (θ). The most common formulas for calculating unaliased frequency with dip before and after migration are:

$$Bin\ Size = \frac{V}{2nf\sin(\theta)}$$

$$Bin\ Size = \frac{V}{2nf\tan(\theta)}$$

where n is the number of cycles per wavelength (typically 2, although some geophysicists use 3), sin(θ) for before migration, and tan(θ) for after migration (Monk, 2020).

Opinions on which velocity (average, RMS, interval) and which frequency (dominant, maximum) to use varies. In general, slower velocities, higher frequencies, and steeper dips required a smaller bin size to avoid aliasing (Fig 1).

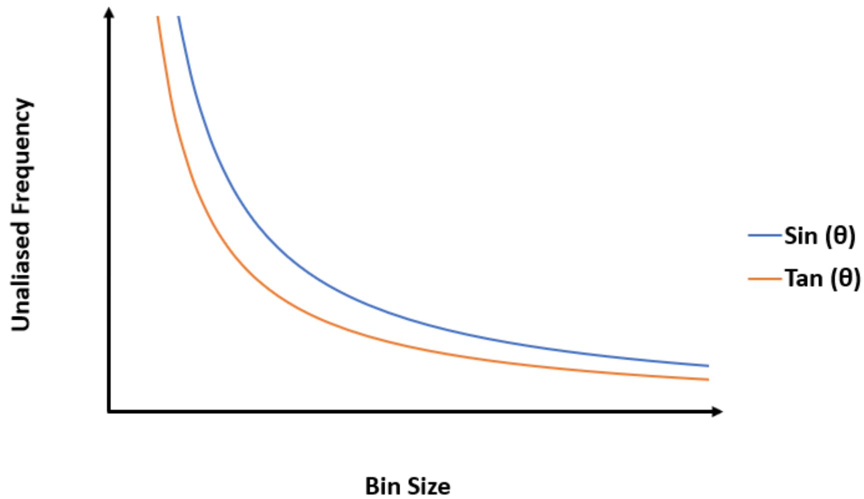


***Figure 1:*** *Graph illustrating the relationship between Bin Size and Unaliased Frequency at a single Velocity for both the pre and post migration calculations.*

## Offset considerations for steep dips

When designing a seismic program for a target with steep dips, it is critical to ensure sufficient offsets are acquired. There are three important considerations when it comes to maximum offset and steep dips: (1) maximum offset of the seismic gather, (2) extent of the surface survey area, and (3) a sufficiently large energy source to record at far offsets.

When determining what the maximum useable offset of the data will be, the geophysicist should consider not only mute offset and stack requirements, but also pre-stack requirements such as offsets required for Angle-versus-Offset (AVO) and Angle-versus-Azimuth (AVAz). The maximum offset needed for these will help to determine the line intervals and the recording patch size, which will need to be larger than what would be used for a survey with shallower dips. In areas with complex dips and deep targets, modeling of the offset response may be required.

The surface survey area for a target with steep dips will need to be larger in the dip direction than a similar survey with shallow dips. This is to ensure adequate offsets for migration (Crook, 2020). At 45 degrees, the theoretical migration distance is equal to the depth of the target (Fig. 2), however, in practice curved ray paths reduce the required migration apron (Bee et al., 1994).

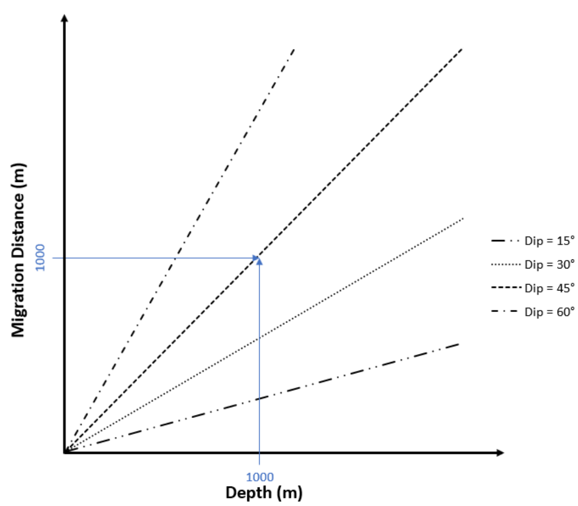


***Figure 1:*** *Theoretical migration distance based on the formula Migration Aperture = Depth x Tan (Dip)*

Finally, when acquiring data for deep targets with steep dips, very long offsets may be required. It is important to ensure that the source type will generate sufficient energy for recording at these far offsets. With explosive sources, charge size will need to be considered since larger, deeper charges typically provide more energy at far offsets. If a Vibroseis source is utilized, it is recommended that sweep parameters tests be conducted at the start of recording operations in order to ensure sufficient energy at far offsets. Geophone pre-amplifier gain settings can be set to enhance far offset signal, but care must be taken not to overdrive near traces.

## Summary

As with all seismic survey designs, when designing seismic surveys for targets with steep dips, it is important to consider frequency resolution requirements, desired offsets, survey size, and equipment type. Surveys designed to image steep dips will require longer offsets and will have a larger surface area in order image the steeply dipping reflections and properly migrate the data. With careful planning, good quality data for surveys with steeps dips is achievable.

## Acknowledgements

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### References

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