GC Tying 2-D Seismic Lines in Overthrust Settings*

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General Statement

In the rough terrain of overthrust settings, 2-D seismic data continues to be a standard tool for subsurface mapping – and not only because of economic reasons. Two-D and 3-D seismic surveys are complementary in land environments, because each data type has its own strength and weakness.

Three-D seismic data gives us a three-dimensional image volume of the subsurface, with no out-of-plane energy problems or potential to miss structural details between 2-D profiles. With such limitations in 2-D seismic data, one might argue that a better exploration strategy would be to just shoot 3-D surveys and not bother with 2-D seismic data, which may be getting obsolete. However, in land seismic acquisition with rough terrain and heavy vegetation, access restrictions make the logistics difficult and expensive to acquire 3-D seismic data with high density. Two-D surveys give us overall higher fold and much higher resolution – and the improved resolution in the shallow section helps us tie surface geology to the subsurface reflectors.

Where 2-D and 3-D data overlap, the 2-D lines can complement the 3-D interpretation with a higher-resolution perspective. So, for scientific as well as economic reasons, 2-D seismic data will continue to be a mainstay in resource exploration in compressional and transpressional geologic settings. One of the major pitfalls when interpreting 2-D seismic data is dealing with out-of-plane reflections, especially when trying to tie intersecting lines in structured areas. Structural geologists and interpretation geophysicists can understand the problem of reflection event correlation across intersecting depth profiles and overcome the difficulty by considering the direction of propagation of seismic energy.

Tying 2-D Profiles in Structure

When processing seismic images in thrust-belt areas, it is rare that we are able to make a perfect tie between intersecting 2-D lines. It is possible to manage the mistie in the time shifts and wavelet character differences between lines, but when we have dipping reflectors on our seismic data, the reflection energy will be coming from out of the 2-D plane of acquisition, resulting in a mistie in time that a simple static shift cannot repair.

Figure 1 shows two intersecting depth-migrated lines over a thrusted structure in the foothills of the Andes. The left half of the figure shows the dip line. The dips in the overthrust range between 10 degrees and 30 degrees. The right side if the figure is the intersecting strike line. Note that there is a reasonably good tie between the two lines below 3.5 kilometers depth, where there are relatively flat layers in the footwall. Above the fault (~3.3 kilometers depth at the intersection), the reflectors on the strike line do not line up with the reflectors on the dip line. The layers in the shallow section are dipping, so the reflectors on the strike line are imaged from out of the 2-D plane.

Since we illuminate the reflectors at angles near the bedding-plane normal, if one wanted to correlate these dipping reflectors, then one would need to align the sections along the bedding-normal direction. Figure 2 shows the improvement in reflector alignment in the shallow section if we rotate the strike line 10 degrees counterclockwise about the intersecting point at the surface. In this orientation, the correlation is along a direction normal to bedding on the dip line.

After the rotation (Figure 2), the reflector alignment is significantly improved between dip and strike lines in the hanging wall. The footwall reflectors, which are more flat, do not tie as well in Figure 2 as with the vertical tie in Figure 1, because the normal-to- bedding direction of these layers is near vertical. Even though the strike line imaged the subsurface reflector outside of its 2-D plane, we still can correlate the two lines by orienting the strike line in the direction normal to bedding. There will still be challenges in creating a 3-D structure map, but at least one may tie the reflectors between lines to ensure consistent mapping over the entire area of 2-D coverage.

Conclusions

When tying 2-D lines in structure, one must not only consider possible differences in static shifts and the phase of the seismic wavelet between intersecting lines, but we also need to consider possible problems with out-of-plane energy. In reasonably simple geometries with gentle dips, rotating the seismic section at the surface intersection point may simplify the problem of correlating reflectors between dip and strike lines.

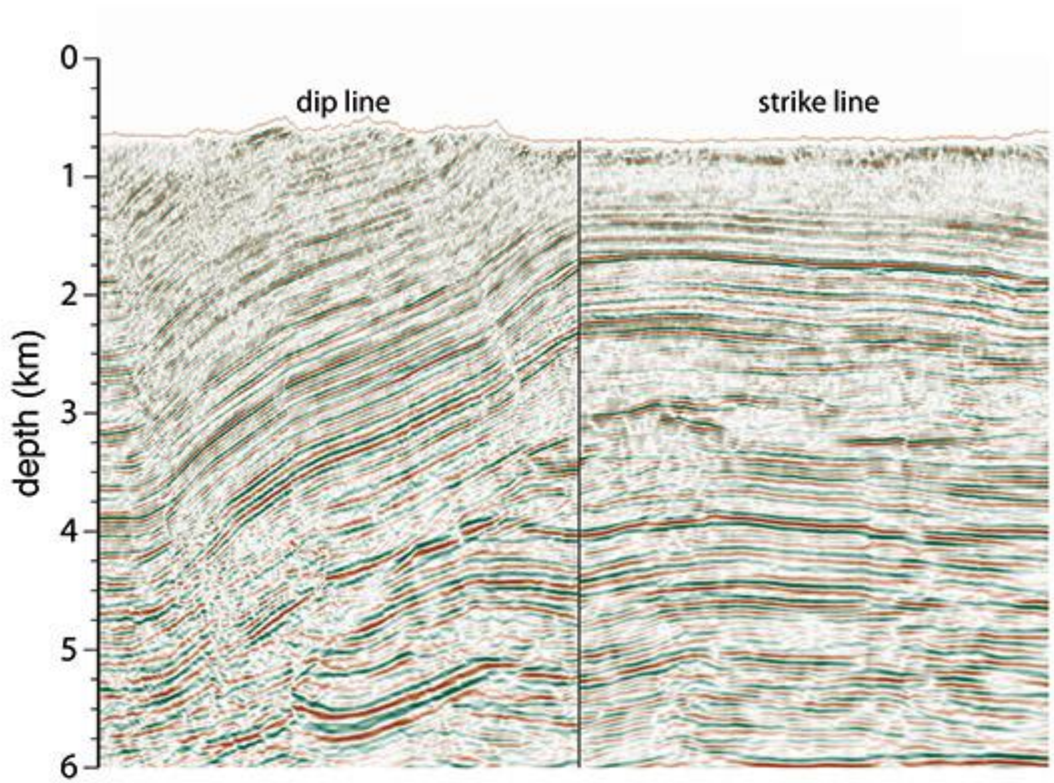

Figure 1. Correlation between the dip line (left) and strike line (right) at the intersection point represented by the vertical black line in the middle of the figure. Between depths of 3.5 and five kilometers the relatively flat reflectors in the footwall correlate reasonably well, but the dipping reflectors above 3.5 kilometers do not correlate between dip and strike line.

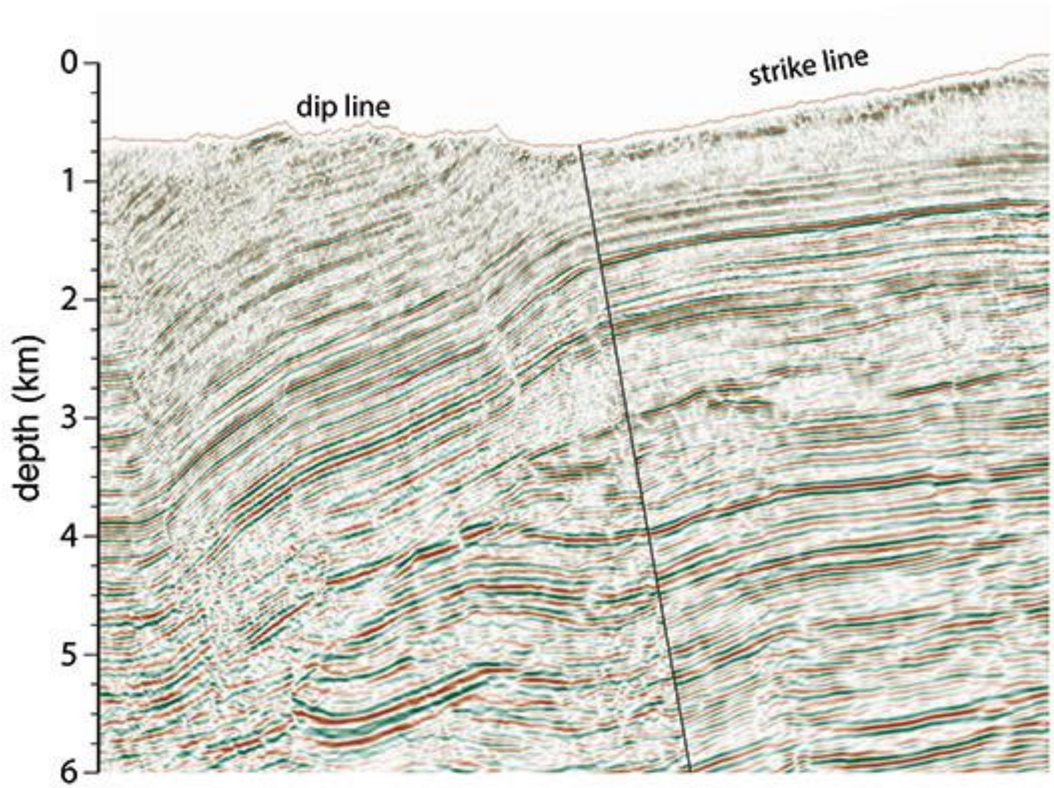

Figure 2. Correlation between the dip line (left) and strike line (right) when the strike line is aligned normal to the layering above three kilometers. Aligning the orientation of the seismic tie along the direction of energy propagation makes it easier to correlate hanging-wall reflectors between dip and strike lines.