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Seismic window

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Acquisition footprint or anisotropy

Figure 1 is a seismic amplitude map at the top of a reservoir unit. There is obvious striping, but what is the cause? Such striping is commonly referred to as an acquisition footprint, which may be partly true, but the underlying cause of this phenomenon is velocity varying with azimuth or azimuthal anisotropy. Acquisition footprint is characteristically strongest on the shallowest horizons and diminishes with depth, so if this is a footprint it should be observed on the shallower horizon of Figure 2, but it is not.

I first encountered this striping when searching for oil prospects in the Exmouth Sub-basin 15 years ago. At the time Mark Stanley (then at BHP) was processing a large 3D survey and was investigating the cause of the striping, which was particularly strong

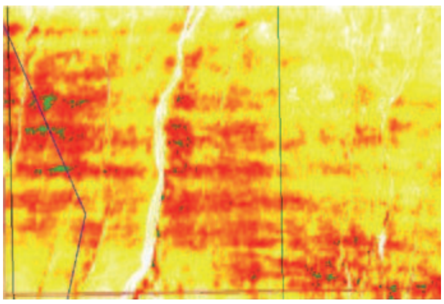

Figure 1. *Map of seismic amplitude at a relatively deep hoizon corresponding to the top of a reservoir. This map has obvious E–W striping which is often refered to as acquisition footprint, but this is incorrect even though the striping is parallel to the acquisition direction.*

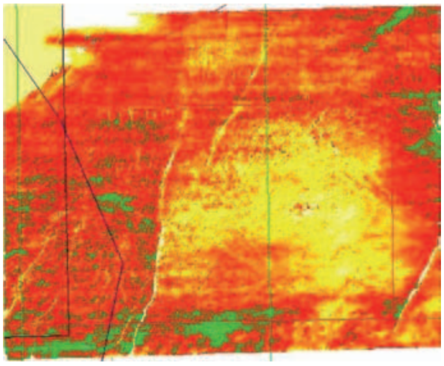

Figure 2. *This is a map of seismic amplitude at a shallow horizon and it has far less striping than the deeper horizon of Figure 1 suggesting it is not caused by acquisition geometry.*

on the reservoir reflector. Something at depth was affecting the data and it was eventually found to be azimuthal anisotropy of velocity in sandstones of the Barrow Group. Independently it had become standard procedure to acquire a cross dipole sonic log in exploration wells. This tool was able to measure shear wave velocities, which were useful for modelling AVO responses and in cross dipole mode could measure the variation of shear velocity with azimuth. These logs found a velocity variation related to the local stress direction, commonly up to 10–15%, that was only observed in the Barrow Group section in the area.

How does a varying velocity cause striping in amplitude and travel time maps? Mark came up with the following explanation, or at least a similar one. Figure 3 shows a schematic seismic acquisition spread and an ellipse representing the horizontal velocity. Because of the different angles relative to the fast velocity direction, the velocity from source to near and far receivers varies across the spread. I have attempted to illustrate this with ellipses where the long axis indicates the fast velocity direction, and the short axis is the slow direction. When travelling west velocities in the northern half of the spread are slower than the southern half, and when travelling east the northern half of the spread is fast compared to the southern half. The central traces are recorded in the average velocity direction. By plotting the relative times on a schematic pre-stack gather (Figure 4) the cause of the striping starts to become more obvious.

Points A1–A4 plot off the average velocity trend with A1 delayed relative

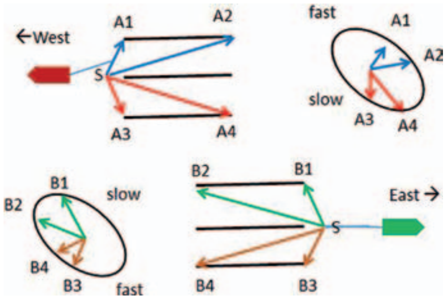

Figure 3. *Acquisition schematic showing raypath directions relative to the fast velocity direction. In this area there is strong azimuthally varying velocity anisotropy (represented by the ellipse with long axis in the fast velocity direction). When travelling E to W (top row) the near traces A1 and A3 travel in the slow velocity direction, far trace A2 travels in the average velocity direction and trace A4 is close to the fast velocity direction. Similarly when travelling west ray paths B1 and B2 are aligned with the fast direction (bottom).*

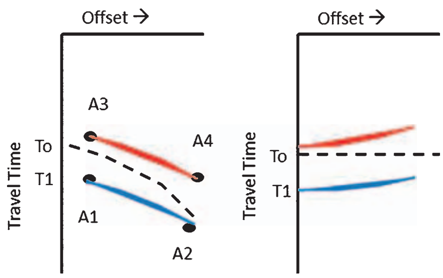

Figure 4. *Stylised uncorrected (left) and corrected (right) gathers. There is a time delay on traces recorded along the slow direction (e.g. A1) and if move-out correction uses the average velocity the reflections from outer traces will be overcorrected leading to diminished amplitude when stacked. When towed in the opposite direction there is a similar result.*

to A3 and A4 early relative to A2. These time differences result in an apparent slower velocity when compared to the average velocity. It is also apparent that if the reflectors are corrected with the average velocity they will be over corrected, and stacking these non-flat gathers will result in a reduced amplitude as well as a time delay relative to the correctly flattened traces.

In a typical racetrack acquisition pattern (Figure 5*a*) adjacent swaths have a time difference if recorded in the same direction and a saw tooth pattern is seen on cross lines (Figure 5*b*).

The result is striping of both amplitude and time maps in the sail line direction.

The amplitude and relative time of a reflection on a cross line XY across the sail lines (Figure 5) shows amplitude

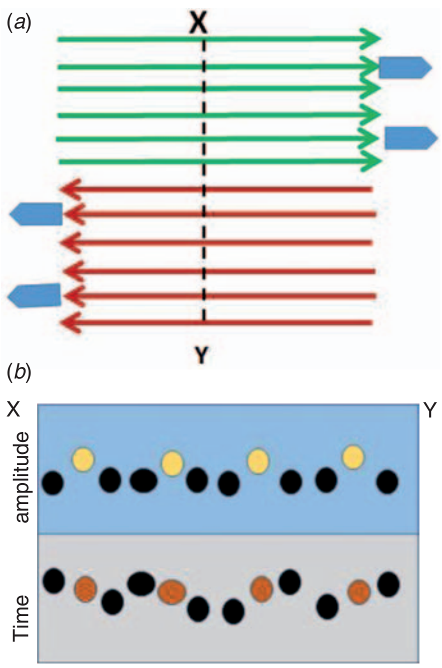

Figure 5. *Acquisition spread with two swathes recorded in each direction (a). The centre traces of each swath aligns with the average velocity direction and have true amplitude and relative time while the outer traces have relatively early or late time depending on the direction of recording and reduced amplitude because non-aligned traces are stacked. Amplitude and time along a crossline XY (b) shows the variations (centre traces coloured).*

variations resulting from mis-stacking and time variations because of the azimuthally varying velocity. Both cause the observed stripes.

Azimuthally varying velocity results in time and amplitude striping and while it is caused by the acquisition direction relative to the fast velocity direction it is not really an acquisition footprint.

This survey had possibly the worst sail line direction relative to the fast velocity direction. By recording parallel to the fast velocity azimuth the effects of anisotropy can be minimised.

Fortunately processing algorithms have been developed to take these velocity variations into account and the effects can be effectively reduced.