The Impact of Shear-Wave Splitting on the Imaging of P-S Data

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Summary

The existence of shear-wave splitting on shear-wave seismic data has been recognized for many years. When shear-wave splitting exists on P-S converted-wave data, reflection energy exists not only on the radial component, but on the transverse component as well. Until recently a common method of processing and interpreting P-S data has been to use only radial component images and assume, or hope, that the shear-wave splitting effects are small. In cases where shear-wave splitting appeared to be significant, extra processing to generate volumes of the two split shear-waves, P-S1 and P-S2, can be performed, but often only one dominant rotation angle for the entire survey would be determined from the data, and applied.

Techniques of analysing and processing converted-wave data have now advanced to the point where more detailed examination of the effects of shear-wave splitting can now be routinely done. Over the surface area of a typical 3C-3D survey there is often a surprisingly large variation in the magnitude of shear-wave splitting as well as a lot of variation in the orientation of the natural coordinate systems associated with the vertical fracturing or horizontal stresses causing the splitting. Removing the effects of the splitting from the P-S data can make a very big improvement in the quality of the final P-S images.

For 3-D surveys, the effect of shear-wave splitting is most easily observed on limited-azimuth stacks. Fig. 1 shows a limited azimuth stack of the radial component. As P-S reflections arrive from different shot-to-receiver azimuths, the variation in traveltime is obviously visible by the sinusoidal variation. The earliest arrival occurs along the S1 (fast) azimuth and lastest arrival occurs along the S2 (slow) azimuth.

The magnitude of the azimuthal time variation can be seen to vary with depth in Fig. 1, so a two-layer analysis of shear-wave splitting was performed. Fig. 2 shows the results of the shear-wave splitting analysis of the shallow layer centred on 600ms. The effects of the splitting on this shallow layer were removed from the data, and a subsequent analysis of the deeper layer centred on 1600ms was performed. Fig. 3 shows the results of this analysis. The colours in these figures indicate the magnitude of the splitting (the time delay between P-S1 and P-S2). The direction of the

needles in these figures indicate the local S1 direction, and the length of the needles is proportional to the splitting magnitude.

In order to image the P-S data most coherently, it is important to remove the effects of the splitting. The right-hand side of Fig.1 shows the limited-azimuth stack with the shear-wave splitting removed in two stages. First the data are rotated to the P-S1 and P-S2 directions according to the shallow layer analysis, P-S2 is shifted to match P-S1 in time, and the two components are combined down to the bottom of the shallow layer. After that, a similar procedure is applied to the deeper part of the data to remove the effects of the deeper layer. Fig. 4 shows one migrated inline stack of the radial component from the 3D. Fig. 5 shows the comparable image of the same data with the effects of the shear-wave splitting stripped off. The improvements in the image, especially on the left-hand side of this inline, are clear.

Conclusions

The effects of shear-wave splitting on P-S data are often significant and should be routinely investigated. The effects can vary significantly both spatially within a small 3D volume, as well as with depth. It is important to be aware of these effects during interpretation and to process the data accordingly.

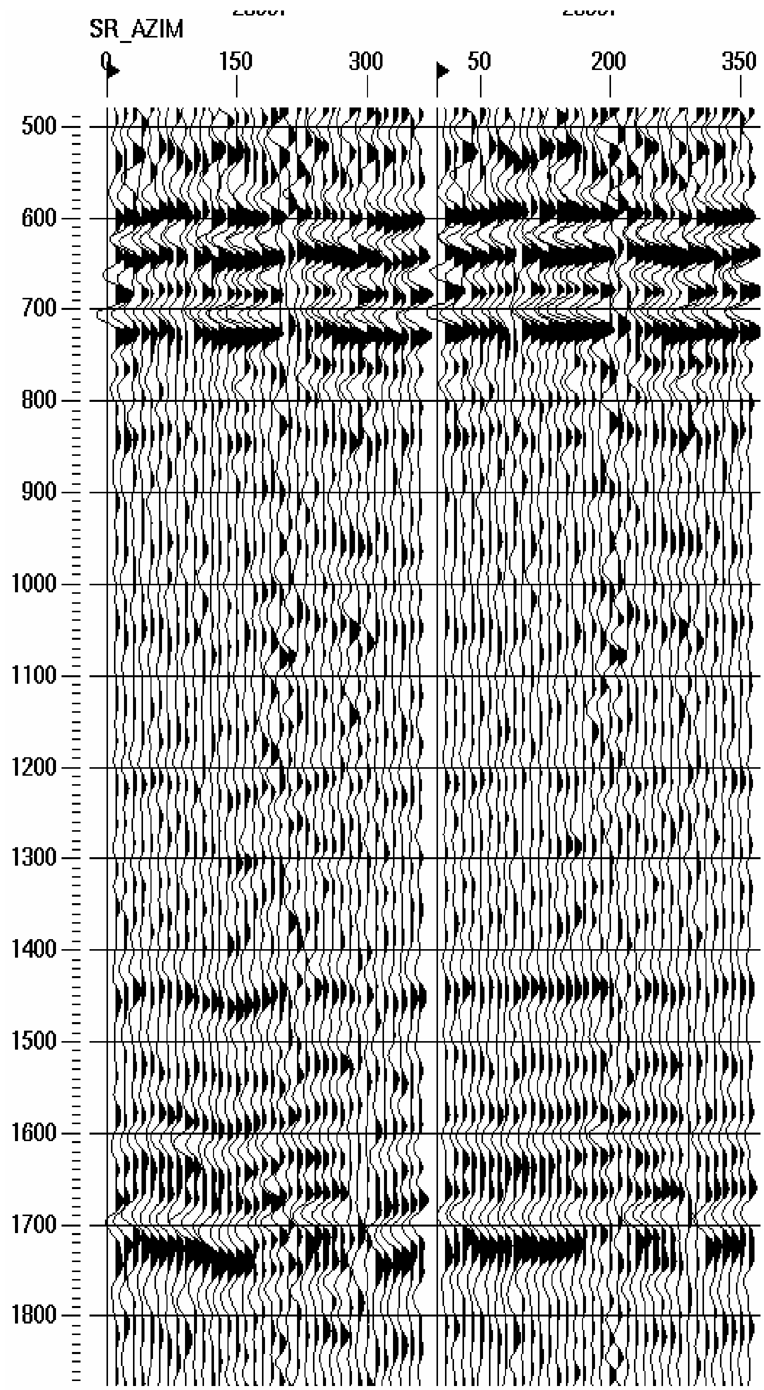

Figure1: A limited-azimuth stack before (left) and after (right) the effects of shear-wave splitting are removed.

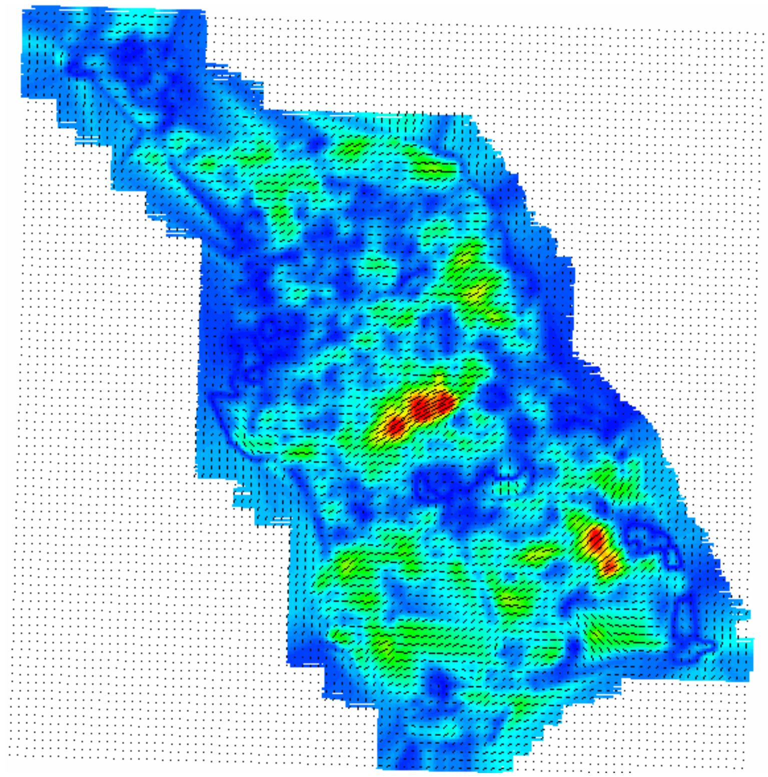

Figure2: Shear-wave splitting occurring in shallow layer. Red colours indicate a maximum of 15ms of splitting. The S1 (fast) azimuth is indicated by the direction of the arrows.

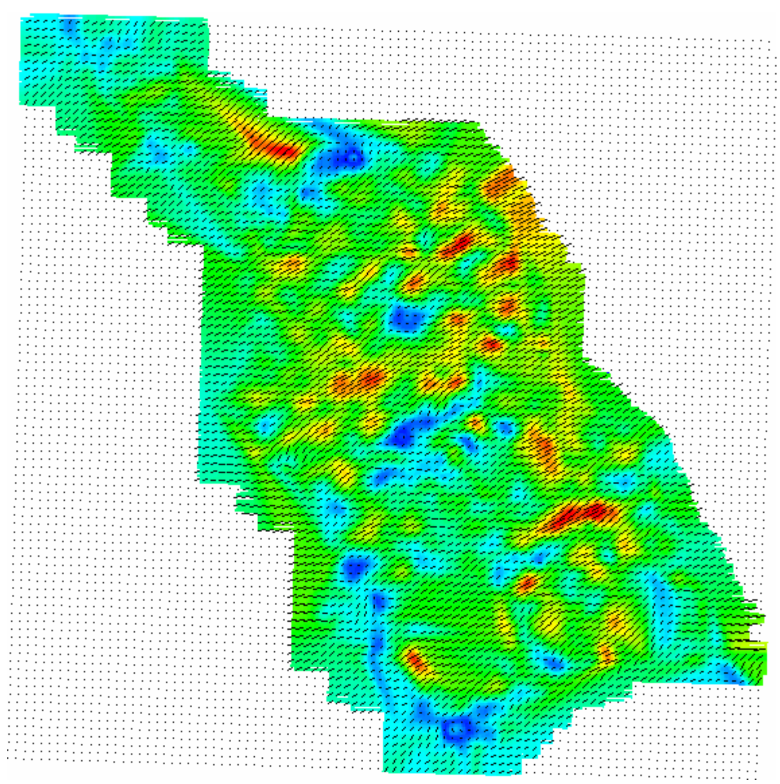

Figure3: Shear-wave splitting occurring in deeper layer. Red colours indicate a maximum of 15ms of spitting. The S1 (fast) azimuth is indicated by the direction of the arrows.

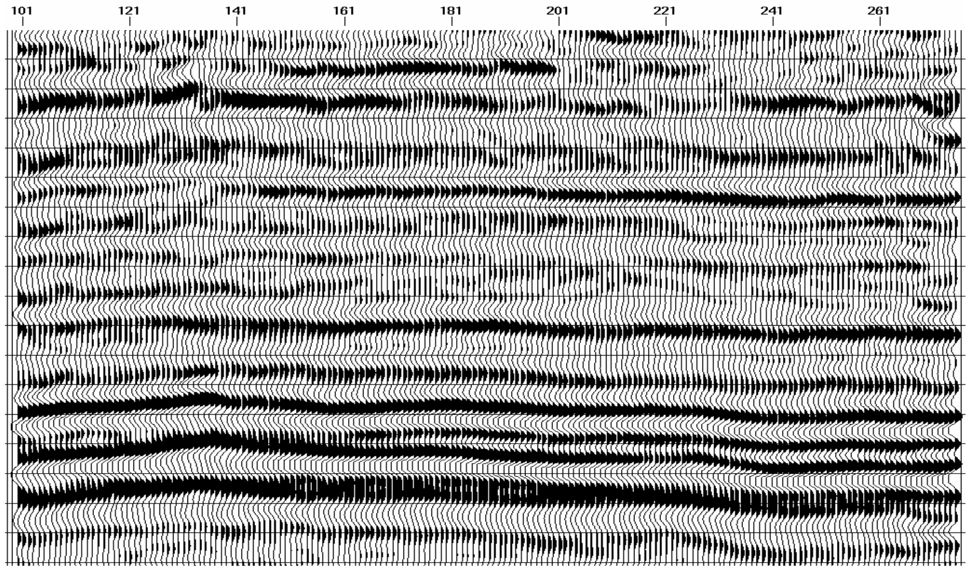

Figure4: Migrated radial component inline from the 3D without the effects of shear-wave splitting removed.

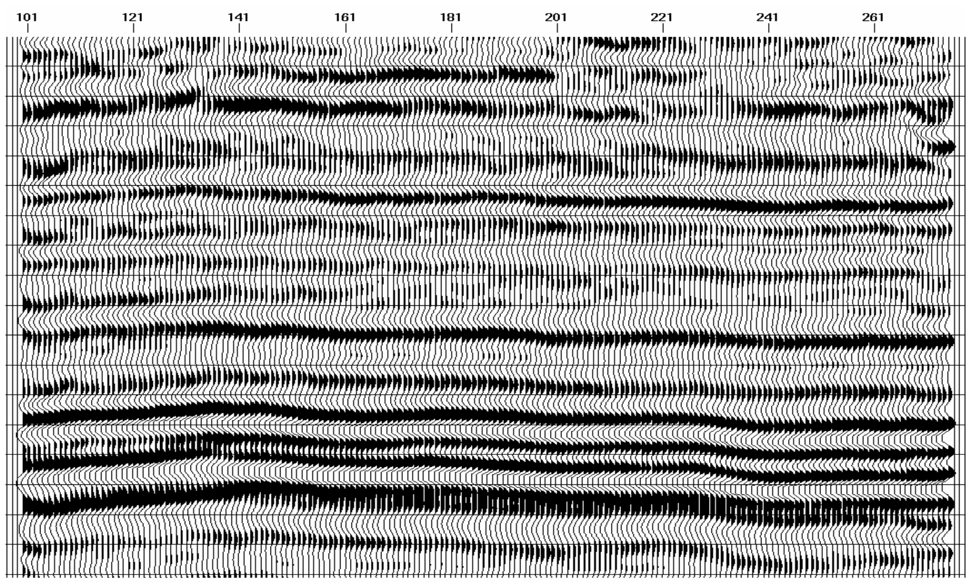

Figure5: Migrated radial component inline from the 3D with the effects of shear-wave splitting removed. There are clear improvements to the image on the left side of the Figure.