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Fracture Analysis with Interpolation Before Prestack Migration

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Introduction

During past decades, fracture analysis became popular for reservoir delineation. Of the fracture analysis tools, azimuthal AVO (AVAZ) is widely used because of its high vertical resolution (e.g. Gray 2007; Zheng et al. 2008; Lynn et al. 2010). It is typically applied to prestack migrated gathers (CIG) so that the fracture attributes can be properly positioned. However, some prestack migration limitations inherited from imperfect acquisition geometry may cause failure of subsequent AVAZ. It is well known that land surface seismic data are inadequately sampled in the spatial domain due to economic and environmental reasons, but migration algorithms require evenly sampled data. Kirchhoff migration can handle irregularly sampled data, but it comes with a price of quality degradation. To overcome these weaknesses, a workflow including amplitude preserved prestack trace interpolation is introduced.

Methodology

It is noticed that irregularly sampled data will cause improper cancellation of migration operators, which introduces erroneous outcomes from the subsequent processes, such as AVAZ, although some smart technologies can reduce the impact of the irregular geometry (Canning and Gardner, 1998; Zheng et al 2001). To solve this issue, one might shoot denser surveys to satisfy the requirement of prestack migration algorithms, but it would be too expensive and make no economic sense. The alternative is to apply prestack trace interpolation to fill the traces where data are not acquired and regularize the data to achieve the even spatial sampling that is required by migration. The basic requirements for this interpolation are preserving (1) geological structures and diffractions; (2) offset and azimuth information; and (3) amplitudes. The Fourier reconstruction interpolation method (Liu and Sacchi, 2004) meets these requirements and tests show it helps reduce migration artifacts and stabilize AVAZ inversion down the road. A practical workflow for AVAZ processing includes prestack interpolation on final CMP gathers, amplitude and azimuth preserved prestack migration and AVAZ inversion.

Examples

The above mentioned workflow has been successfully tested on several datasets. One comparison example is given here. Figure 1 shows a horizon slice of the AVAZ fracture intensity and orientation map extracted from the migrated gathers without prestack trace interpolation. The red color shows high fracture intensity, blue color shows low or no fracture intensity. The short sticks in each CMP bin show the orientation of the fractures. With carefully chosen offset slot sizes and proper weights applied to the data prior to prestack migration, migration artifacts still remain in the migrated gathers, which result in

uninterpretable noise on the fracture map. The same dataset went through prestack trace interpolation followed by prestack migration and AVAZ inversion. The fracture intensity and orientation map is shown on Figure 2, which is interpretable and makes geological sense. Compared to Figure 1, Figure 2 has less noise. The prestack interpolation eliminated migration artifacts and played an important role in extracting fracture information from seismic data.

Conclusions

Prestack migration may deteriorate AVAZ inversion due to migration artifacts introduced by irregular sampling of the input data in space. To eliminate the migration artifacts, prestack trace interpolation can be used to fill in the missing traces and regularize the data to meet the requirements of migration algorithms. Test results show the workflow of interpolation plus prestack migration followed by AVAZ inversion reduces migration artifacts and yields interpretable fracture attributes.

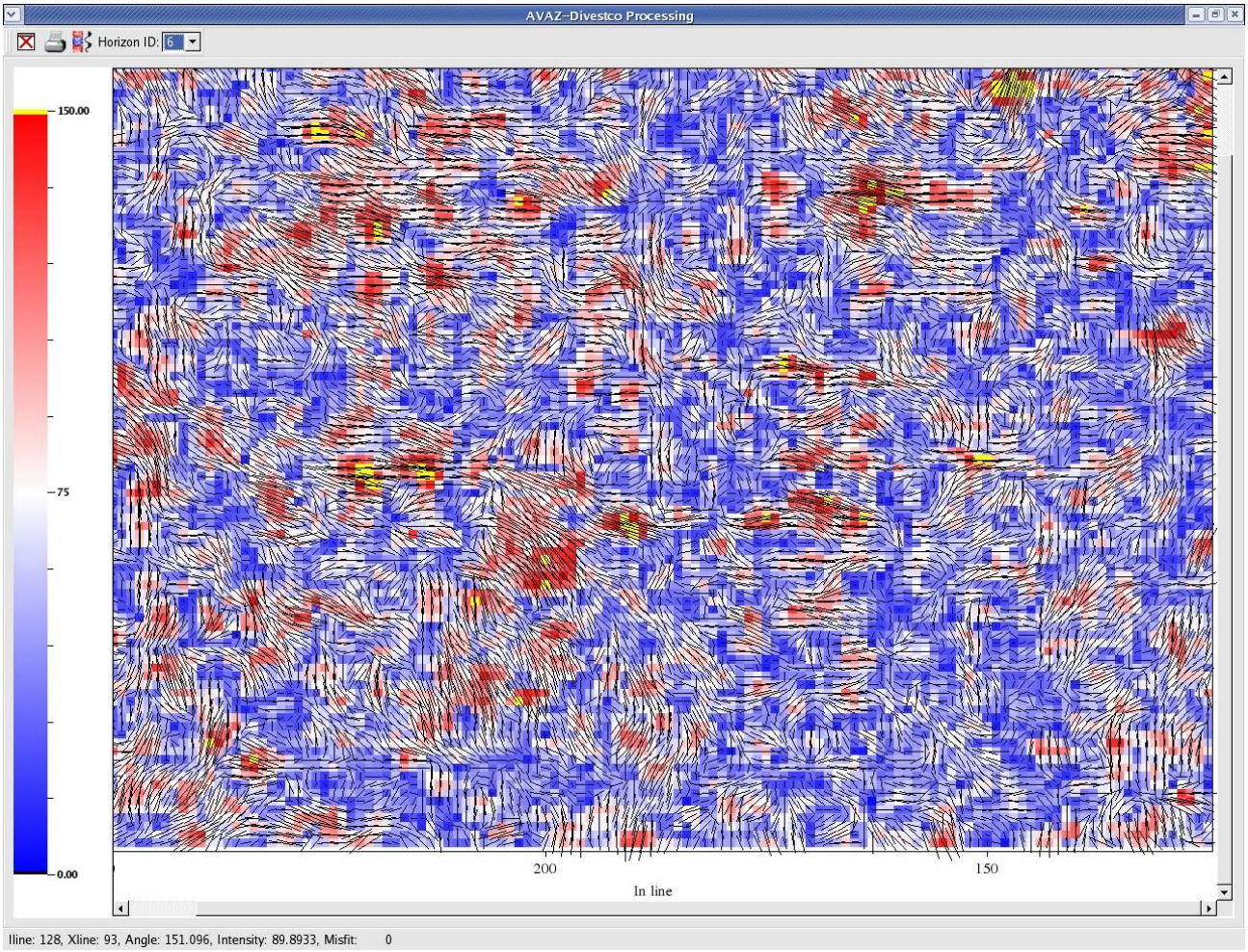

Figure 1: Horizon slice of the AVAZ fracture intensity and orientation map from the migrated gathers without interpolation. The red color shows high fracture intensity, blue color shows low or no fracture intensity. The short sticks in each CMP bin shows the orientation of the fractures.

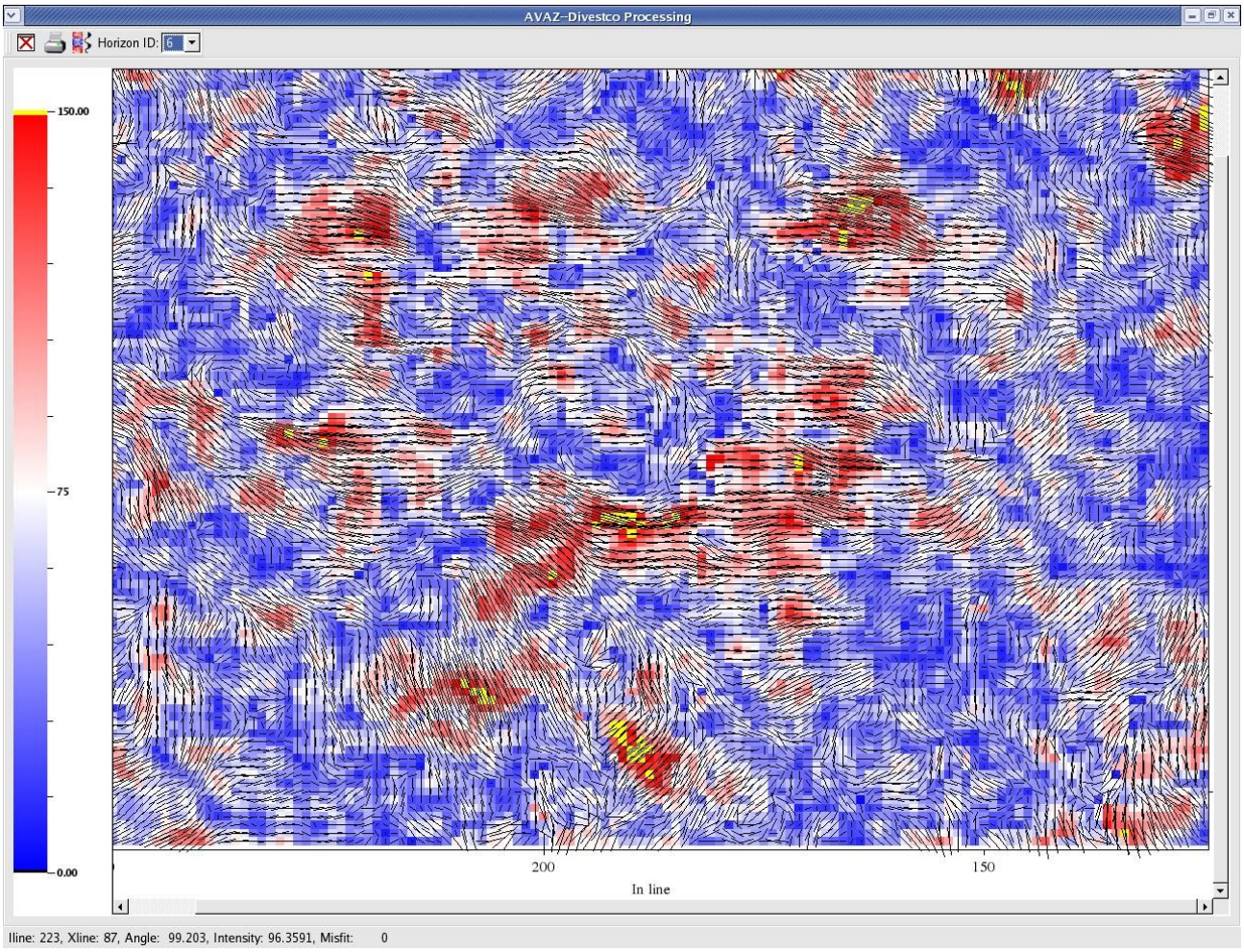

Figure 2. Horizon slice of the AVAZ fracture intensity and orientation map from the migrated gathers with prestack interpolation. Prestack interpolation eliminated migration artifacts. AVAZ attributes are more interpretable and make geological sense when compared to Figure 1.

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