Towards an Optimal Workflow for Azimuthal AVO

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Summary

We examine various workflows for producing Azimuthal AVO attributes, testing them on an Horizontal Transverse Isotropic (HTI) physical model, whose anisotropic parameters replicate fractures and are known exactly. This model has structures carved into the base of the anisotropic layer. Their imaging in the anisotropic gradient, B^{ani} (Rüger, 1996), allows us to determine which workflow is best for Azimuthal AVO. The workflow that produces the best images of B^{ani} found to date is azimuthally-sectored pre-stack migration of 5D interpolated gathers with "Area-Weighting" applied. This will be compared to estimates of B^{ani} derived from migration of Common Offset Vectors (COVs), which seem to be a more natural way of maintaining azimuthal information through migration.

Introduction

We study the processing of seismic data as part of a workflow to generate optimal Azimuthal AVO attributes. Following from the work of Zheng and Gray (2002), Zheng and Wang (2005) and Calvert et al (2008), we examine the effects of various inputs to migration, as well as how 5D interpolation (Trad et al, 2005) interacts with them, on the output of the Azimuthal AVO process on a known physical model (Wang and Li, 2003). An important part of this process is to compare how current practice using azimuthally-sectored migration (Zheng and Wang, 2005) compares with calculating these attributes after migration of the COVs of Cary (1999), e.g. Calvert et al (2008). Furthermore, we determine whether or not "Area-Weighting" (Zheng et al, 2001) is required in these workflows to optimize the Azimuthal AVO attributes.

Method

Our objective is to define a best practice for processing to produce Azimuthal AVO attributes. This is done by examining B^{ani}, the anisotropic gradient, which is the magnitude of the Azimuthal AVO described by Rüger (1996). It is related to the intensity of fracturing (Lynn et al, 1996) and is the most commonly used attribute generated by Azimuthal AVO. B^{ani}, in our experience, has proven to be extremely sensitive to the presence of noise and footprint in the data and so is a useful attribute to test the soundness of these workflows. The tests are done on seismic data shot over the physical model created by Wang and Li (2003) and shown in Figure 1. The direction and magnitude of the anisotropy in this model is known exactly and there are small scale structures, a dome and a ramp at the base of the anisotropic layer, that allow us to determine how well each workflow performs . These small structures are difficult to image (Zheng and

Wang, 2005). All tests involve different pre-processing methods, migration and post-processing. A flowchart showing the tests conducted is shown in Figure 2.

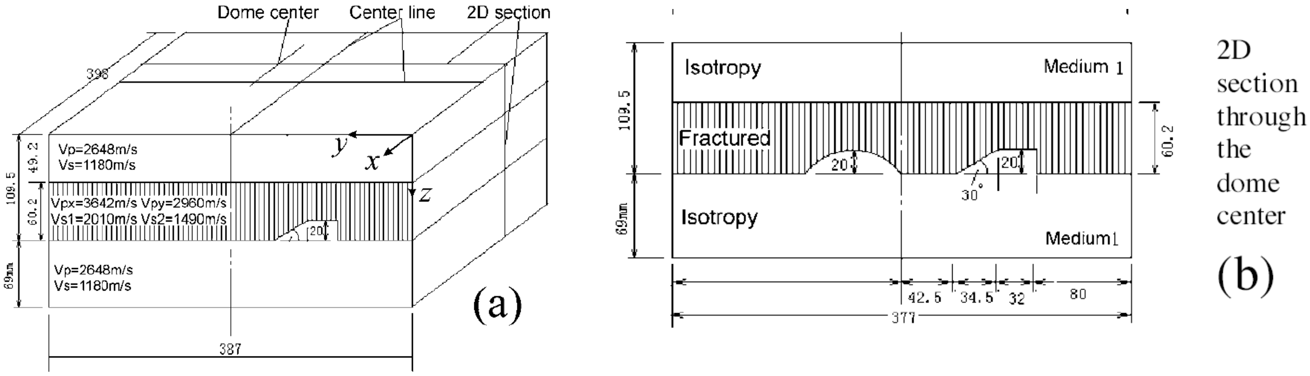

Figure 1: (a) 3D view of the model. (b) A 2D section through the center of the dome. There are two structures on the bottom of the fractured layer, a dome and a thrust fault. The modeling scale is 1:10,000. (After Wang and Li, 2003)

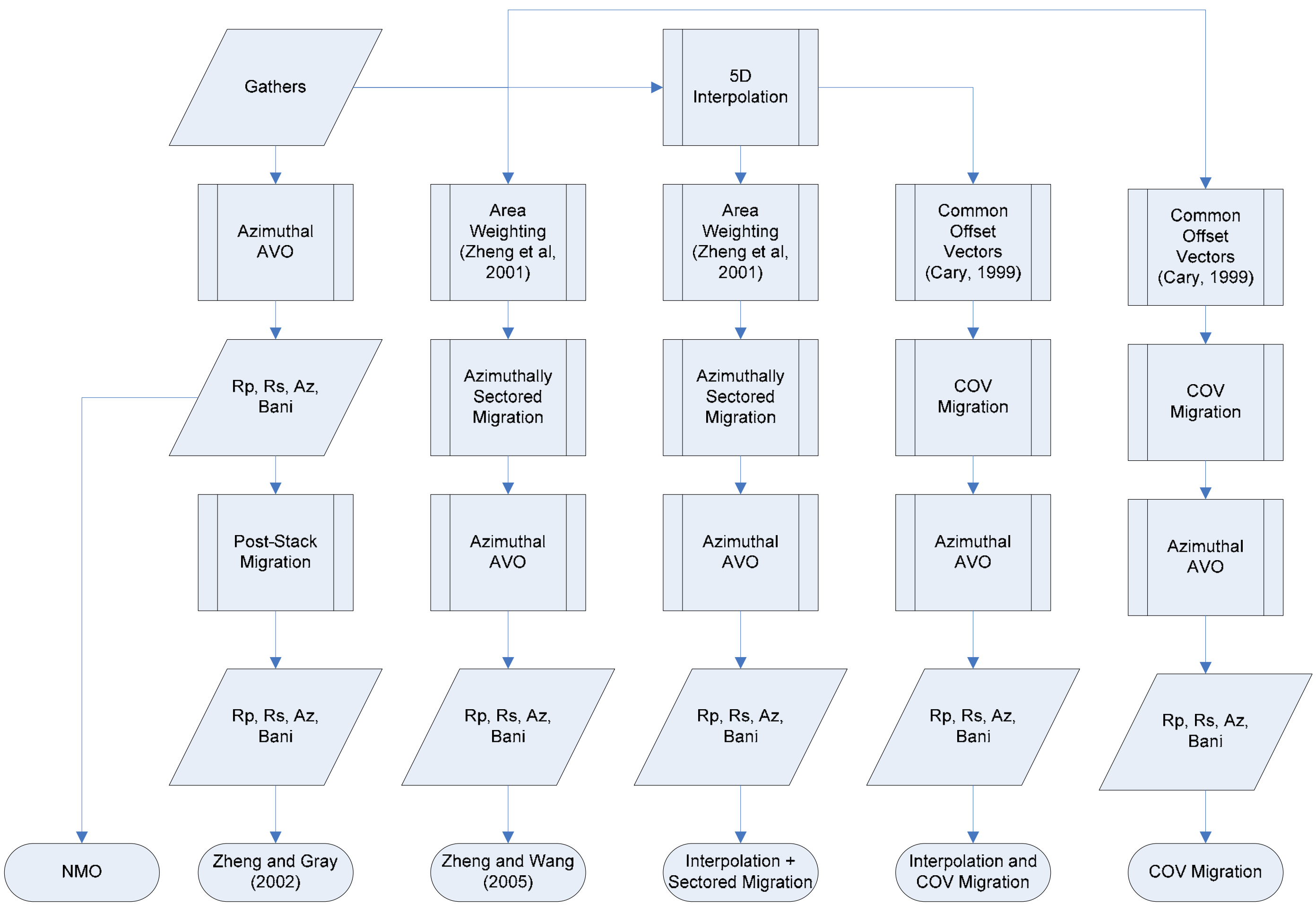

Figure 2: Flowchart showing the various azimuthal processing workflow tests.

Examples

Figures 3 through 6 show B^{ani} generated using some of the processing workflows from Figure 2. It is clear from viewing Figure 3 that estimating B^{ani} in the presence of structure on unmigrated gathers is inadequate. However, Figure 4 shows that the post-stack migration method of Zheng and Gray (2002) does manage to collapse the diffractions to produce an adequate image of the dome in the B^{ani} section, although the 30^{o} slope of the ramp is not so well defined. In Figure 5, B^{ani} produced through the azimuthally-sectored pre-stack migration of Zheng and Wang (2005) images all the structures better than does the post-stack migration. An important part of this flow is area-weighting (Zheng et al, 2001), which substantially reduces migration noise. Prior to the introduction of area-weighting to this pre-stack migration workflow by Zheng and Wang (2005), its images were far worse than the post-stack migration workflow. Figure 6 shows the best result we have to date, in which the azimuthally-sectored pre-stack migration from Figure 5 is applied to gathers that have been interpolated using the 5D interpolation of Trad et al (2005). There is a clear improvement in the amplitudes and noise level of B^{ani} in Figure 6, with 5D interpolation, compared to B^{ani} in Figure 5, which is the same workflow without interpolation.

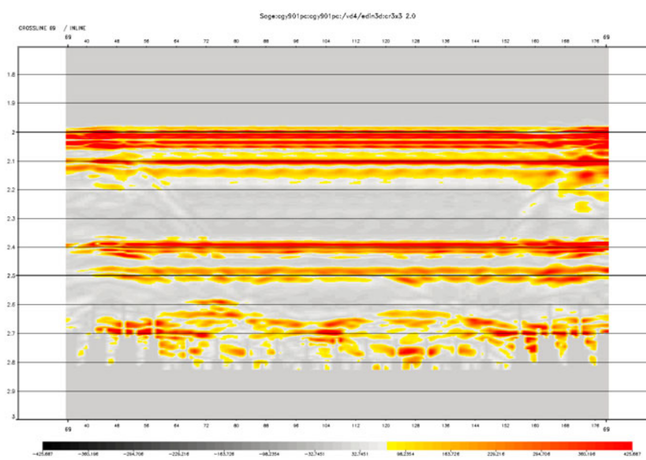

Figure 3: B^{ani} from NMO gathers.

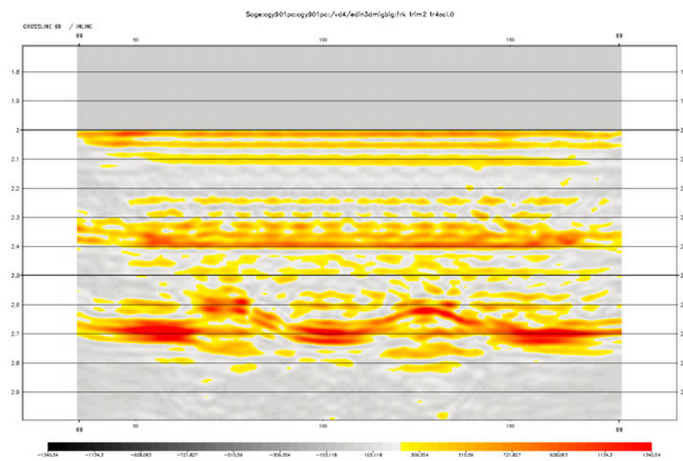

Figure 5: B^{ani} from azimuthally-sectored pre-stack migration with area-weighting (Zheng and Wang, 2005)

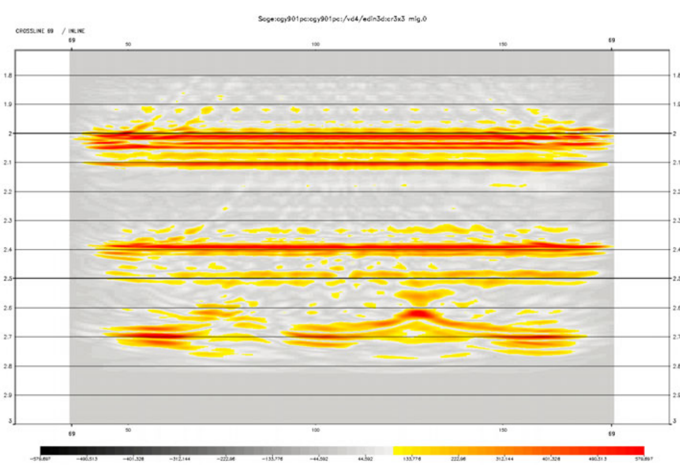

Figure 4: Post-stack migration of the B^{ani} result shown in Figure 3 (Zheng and Gray, 2002).

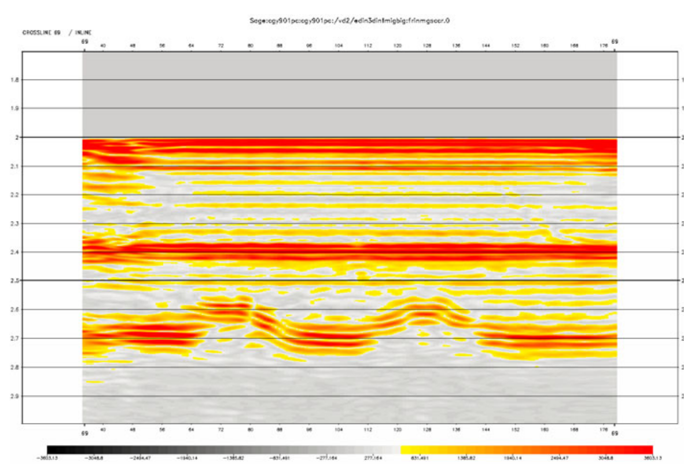

Figure 6: B^{ani} from azimuthally-sectored pre-stack migration with area-weighting after 5D interpolation of the gathers (Trad et al, 2005).

Conclusions

B^{ani}, the magnitude of anisotropic gradient of Azimuthal AVO, has been generated using several different processing workflows on data shot over the physical model of Wang and Li (2003). This dataset was chosen for these tests because its azimuthal anisotropy is known exactly and there are two small structures, a ramp and a dome carved out of the base of the anisotropic layer that allow us to test different processing tactics. B^{ani} is very sensitive to noise in the data and so is a good attribute to use to test these workflows. Estimating B^{ani} from NMO gathers in the presence of structure is completely inadequate. The structures at the base of the anisotropic layer in this example are barely visible and too wide without migration. The post-stack migration method of Zheng and Gray (2002) applied to B^{ani} output from the NMO workflow does a remarkable job of imaging these structures and may be suitable for quick-look anisotropy analysis in mildly structured areas. Azimuthally-sectored pre-stack migration does a better job of imaging the structure in the B^{ani} section than post-stack migration. The best workflow we have to date uses 5D interpolation of the input gathers followed by azimuthally-sectored pre-stack migration using area-weighting. This produces B^{ani} sections that are much more stable in amplitude than the same workflow without 5D interpolation. Further work will test the migration of COVs using both conventional and interpolated data. The COVs are a natural way of organizing the data and maintaining azimuth information through a migration and so may be as good as or better than our best result to date which is azimuthally-sectored migration of 5D interpolated gathers.

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