GeoConvention 2015
GEOSCIENCE
new horizons
Telus Convention Centre • 4-8 May 2015 • Calgary, AB Canada

Multi-attribute fracture analysis of the Washout Creek 3C3D data set

Michael J. Perz, Xinxiang Li, Wendy Ohlhauser, Ritesh Kumar Sharma, Peter Cary, Satinder Chopra
Arcis Seismic Solutions, A TGS Company

Summary

The following work builds on results presented at the 2015 CSEG Symposium. It is a case-study centred on fracture analysis and reservoir characterization of the Washout Creek 3C3D data set from central Alberta. In particular we generate attributes via four different fracture characterization approaches: shear-wave splitting (“SWS”) analysis using the PS data, azimuthal AVO (“AVAZ”) and velocity (“VVAZ”) analyses using the pre-stack PP data, and curvature analysis using the post-stack PP data. In addition multiple reservoir characterization attributes are computed using three different algorithms: simultaneous PP pre-stack inversion and joint PP-PS post-stack and pre-stack inversion. The various attributes are examined concurrently in a common look-and-feel viewer and details regarding workflow construction and result interpretation are addressed. Anisotropy maps generated via SWS and VVAZ approaches show good agreement in orientation but puzzling differences in intensity patterns in the shallow section; in the deeper section the layer-stripped SWS and VVAZ show some similarity in both orientation and intensity.

Introduction

Seismic tools for fracture detection have found their way into the geophysical mainstream. However despite some impressive success stories and despite the fact that 20 years have elapsed since the related seminal publications, the truth is that these tools still lack universal acceptance by geologists and reservoir engineers. The fact that these techniques continue to occupy “emerging technology” status can probably be linked to two main factors: first, we are trying to squeeze very subtle effects out of noisy and likely undersampled data volumes, and second, there are big challenges in relating our various attribute maps--each carrying its own assumptions and characteristic measurement scales--to the complicated fracture properties of the rocks in the real world. An additional compounding effect is the fact that the technology naturally straddles the diverse fields of signal processing, interpretational geophysics, rock physics, geomechanics, reservoir engineering and geology, creating a situation wherein no one person is expert in all areas, and yet for which interdisciplinary communication is paramount. An obvious approach to reducing uncertainty in analysis is to co-interpret multiple fracture attributes which are generated via independent means. This is a good idea, and indeed seems to be a generally accepted practice. Unfortunately the two main factors noted above often conspire to present the practitioner with a confusing mess at first blush in which attribute maps appear inconsistent, perhaps showing maddening correlation in a few places but not in others.

Fortunately science, logic and attention to detail can quell the confusion in many cases. Through case-study, this talk will expand on the notion that employing these three key elements can indeed lead to meaningful result interpretation. The Washout Creek 3C3D data set was acquired in March 2014 and was designed to evaluate multiple zones from Cretaceous to Devonian, including the Cardium and Duvernay formations. All four of the seismic fracture attributes in common use today were generated for this data set (SWS, AVAZ, VVAZ, curvature) as well as numerous additional attributes such as Vp/Vs, P and S impedance, LMR attributes, and density (this latter attribute being generated by the joint PP-PS inversions). In the oral presentation we will visualize results in a common-look-and-feel viewer containing numerous tools for data QC and wellbore verification, and will thereby showcase a practical workflow for fracture and reservoir attribute analysis. In addition, we will make what seem to be geologically meaningful inferences about the fracture and stress regimes at various intervals in the stratigraphic column. Finally, we hope to show some new aspects of the interpretation which were not presented at the CSEG Symposium.

Examples

The multiple inversion schemes employed in this case study obviously give rise to a very large number of attributes. Key comparisons and analyses will be shown in the oral presenation; here for brevity we show just one representative example. Figure 1 shows the result of running shallow VVAZ (right) and SWS (left) analyses aimed at characterizing anisotropy in the shallow overburden. We have decided to focus on a comparison of VVAZ and SWS since both techniques detect the anisotropy at similar characteristic measurement scales. Note that the orientation fields (arrows) are approximately uniform and trend NE-SW in both cases, an observation which is consistent with the known direction of maximum regional horizontal stress in the area. These two maps suggest that both VVAZ and SWS have succeeded in measuring the vertically pervasive modern-day horizontal stress anisotropy. It is puzzling to note that the anisotropy intensity maps (colour) do not show much, if any, spatial correlation. Careful data QC (not shown here) reveals that both PP and PS pre-stack data quality is very good, a finding which in turn suggests that the root cause for the discrepancy in intensity likely exists at the rock physics level. One possible explanation, though untested, is that shallow vertical cracks are fluid-filled in some parts of the survey and cemented in others, a situation which could cause compressional and shear waves to exhibit markedly different anisotropic responses (Mark Chapman, pers. comm.)

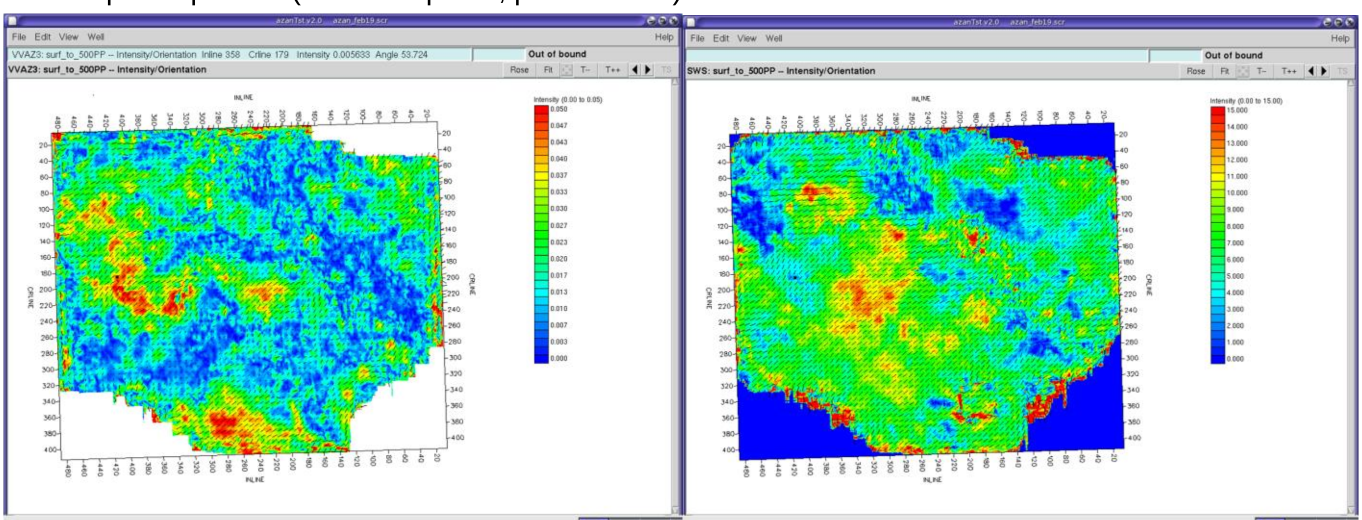

Figure 1: VVAZ (left) and SWS (right) anisotropy maps characterizing the shallow overburden, corresponding approximately to 0 - 500 ms PP time. Data courtesy of Arcis, A TGS Company.

Figure 2 shows the result of running VVAZ (left) and SWS (right) analyses aimed at characterizing anisotropy in the deeper Viking-to-Banff interval. To our knowledge, this is one of the first-ever published comparisons between layer-stripped SWS and VVAZ. In order to ensure proper vertical localization of the anisotropic response within the desired interval, three passes of layer-stripping were employed in the SWS analysis and traveltime measurements from two bounding horizon picks were used in the VVAZ analysis. In this case we observe some satisfying similarities and also some differences in anisotropy intensity and orientation bewteen the two maps. Both maps suggest that the overall orientation field is no longer uniformly oriented NE-SW; furthemore, both attributes show the same “macropatterns” in spatial variation of orientation, particularly on the left hand side of the maps. Both attributes also arguably show some similarities in the intensity fields.

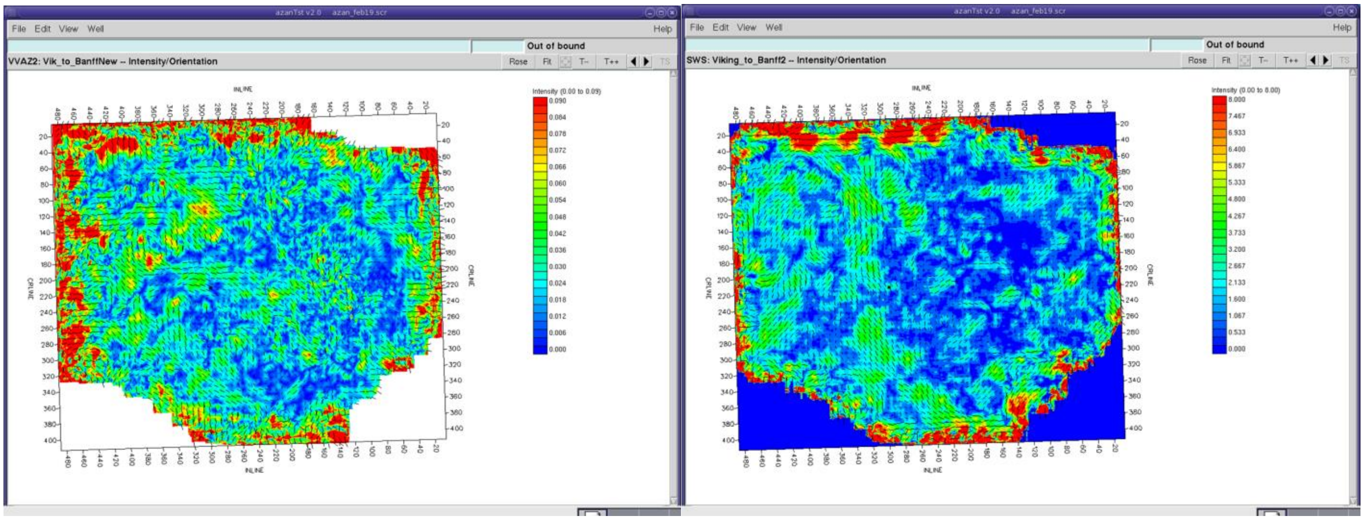

Figure 2: VVAZ (left) and SWS (right) anisotropy maps characterizing the Viking-to-Banff interval, corresponding approximately to 1300 to 1500 ms PP time. Data courtesy of Arcis, A TGS Company.

Conclusions

Diverse fracture and reservoir attributes have been analyzed concurrently in a common look-and-feel viewer. Anisotropy maps generated via SWS and VVAZ approaches show good agreement in orientation but puzzling differences in intensity patterns in the shallow section. In the deeper section the layer-stripped SWS and VVAZ show some satisfying similarity in both orientation and intensity. Additional significant elements of our interpretation will be discussed in the oral presentation.