C041

TTI/HTI Anisotropy for Fracture/Faults Image Inside Granite Basement

J. Zhou* (CGGVeritas), N.H. Ngoc (Thang Long JOC), T. Borthwick (Thang Long JOC), K. Zhao (CGGVeritas) & K.H. Teng (CGGVeritas)

SUMMARY

In this paper, we present a case study of improving the fracture imaging inside granite basement by incorporating the TTI/HTI anisotropy for the first time. With the help of the Controlled Beam Migration (CBM) stack sweeping technology, the new velocity modeling flow can estimate the azimuth information for the fracture system and improve the imaging quality inside the basement, which provides the much needed information for the effective exploration in the Cuu Long Basin offshore Vietnam.
Introduction

The oil-bearing fractured granite basement rocks are a very important and complicated hydrocarbon reservoir in offshore Vietnam. Ever since the first discovery of White Tiger field in 1987, more oil has been discovered and produced in the Fractured Granite Basement which now accounts for 80% of Vietnam’s total annual production (Tran et al., 2008). However, the low S/N ratio and the lack of steep dipping fracture imaging in the conventional Kirchhoff migration result make the seismic imaging difficult to interpret for exploration.

The Hai Su Den (HSD) field, which is located at block 15-01/01 offshore Vietnam, is a good example. After two unsuccessful drilling attempts in the area, Thang Long JOC reprocessed the data and optimized the well location, which resulted in the new oil-bearing discovery in the fractured granite basement in 2008. Figure 1 shows the comparison of seismic imaging for Granite Basement from different processing sequences and migration algorithms. The top left is the early PSTM section, the data is very noisy and the fault is smeared; the top right is the 2007 Kirchhoff Isotropic PSDM section, the fault is sharper than the one from PSTM and some hint of the fracture imaging begins to appear. A Controlled Beam Migration volume was also produced with the same isotropic velocity model and migration input. That result (bottom left) shows higher S/N ratio and sheds more light of the fracture system inside the basement, but overall the imaging quality falls short of the expectation of CBM compared to the its success of surrounding surveys. After review and discussion, it was agreed that the velocity field needs to be refined to take the full advantage of CBM migration algorithm, both the S/N enhancement and the multi-arrival ability. In 2009, the data was reprocessed and a VTI anisotropic velocity was modelled by taking a similar approach as Sun et al, 2008. A CBM based stack sweep method was included for the velocity update inside the basement. This beam result from the 2009 reprocessing (bottom right) generated a much clearer fracture image inside the basement.

![Figure 1: Improvement of Seismic imaging from different processing sequences.](image)

The fidelity of the 2009 Beam result is validated by the well result, good correlation can be observed between the 2009 CBM result and the synthetic well seismogram inside the basement.

Conflict between imaging velocity and well velocity

Although the improvement from 2009 reprocessing is very encouraging, there is still an issue as to the accuracy of the velocity model. In the basement velocity sweeping, it is observed that we need to pick...
the slow velocity (4600m/s~4700m/s) right beneath the basement as the image velocity to get the best fracture image. This is in conflict with the fast basement velocity profile (~5600m/s) from the sonic log information, which also raises the question of the accuracy of the dipping image inside basement.

Based on the well FMI results, the dominant dipping angle of fractures inside the granite basement in Cuu Long Basin is from 70 to 90 deg. Ray tracing study reveals that the ray path within the basement is mostly influenced by the horizontal velocity instead of the vertical velocity. The fracture inside basement could originate from the cooling of the magmatic body, the tectonic activity or the weathering and exfoliation (Nguyen et al., 2004). In the case of the basement being highly fractured, sound wave will travel faster along the vertical direction (or along the main fracture direction) than along the horizontal direction. Introducing TTI anisotropy could be the solution to solve the conflict between imaging velocity and well velocity inside basement, which is not only observed in this survey but also in surrounding surveys in this region.

**TTI/HTI Velocity model Building**

Poor S/N ratio, influence of the residual multiples and the very low frequency characteristics of the fracture events in the gathers make it impossible to use the gathers to estimate the anisotropy property inside the basement. With the help of CBM stack sweeping technology, our approach is as below:

1. Use CBM stack sweeping to estimate the best imaging velocity inside the basement,
2. Calculate Delta/Epsilon inside basement based on imaging velocity and well velocity (Delta/Epsilon above the basement won’t change),
3. Estimate the main dipping angle for the fracture system (in this case, dominant dips are above 70 degrees, so we set dipping angle as 90 degrees and it simplifies to a HTI case),
4. Calculate velocity along the axis of symmetry,
5. Get main azimuth direction from the provided well and geological information then run CBM stack sweeping using different azimuth angles,
6. PSDM with final TTI velocity model.

The azimuth direction in the anisotropic model is more related to the orientation of the micro fractures system, which is below the seismic resolution; it may not be consistent with the large regional fault or macro fractures lineation seen on the seismic section. The success of step 5 depends on the sensitivity of the seismic image to the azimuth angle in the TTI/HTI model, and it turns out that the fracture image is strongly influenced by the azimuth angle used in the model (as in figure 2).

Figure 2: TTI CBM stack with different azimuth angles.
Six different azimuth angles (0, 30, 60, 90, 120, and 150) are used to generate six CBM stack volumes. These volumes are loaded into the stack sweeping tool to determine the best azimuth angle based on the best stacking response of the fracture image. A refinement of 10 deg was further added around two domain angles (60 deg and 90 deg) to improve the resolution of the picking. Due to the non-linear nature of the azimuth, we are unable to use the tomography for the azimuth inversion. A simple interpolation of the azimuth picks is applied to create the updated azimuth model (as in Figure 3). Overall, the dominant fracture azimuth is around 60 degrees and 100 degrees measured from the north.

![Updated azimuth angle with picking location and slow velocity direction marked.](image)

**Figure 3: Updated azimuth angle with picking location and slow velocity direction marked.**

**Final TTI/HTI velocity and CBM stack image**

By introducing the TTI/HTI anisotropy, the seismic velocity fits much better with the sonic log velocity from well log within the basement. One benefit from the vertical velocity being faster than the horizontal velocity inside the basement is that the flat or gentle dipping multiple events now see a much faster velocity and thus the migration swing from them is much suppressed while, at the same time, the major fault/fracture is enhanced (as in Figure 4).

![2009 Beam stack (left); 2010 Beam stack with TTI model (right).](image)

**Figure 4: 2009 Beam stack (left); 2010 Beam stack with TTI model (right).**
Impact on interpretation

By the difference of conductivity, the basement fracture in Cuu Long Basin can be divided into three types: discontinuous fracture, continuous fracture and solution enhance fracture. How to identify the distribution of the solution enhance fracture system is the main consideration to optimize the well drilling location. The azimuth angles from TTI model and the improved fracture imaging inside the basement provide the much needed information for the “From Seismic interpretation to Tectonic Reconstruction” methodology, which has been proven to be effective in Exploration in the Cuu Long Basin for the last five years (Ngoc et al., 2010).

Conclusions

The existence of TTI/HTI anisotropy inside the fractured basement is evident through this case study. With the help of CBM stack sweeping technology, we have presented a new velocity modelling flow which can estimate the azimuth information for the fracture system and improve the imaging quality inside the basement in the CUU Long basin offshore Vietnam. The actual earth model is much more complex. We need to incorporate all available information to better understand the fracture system (reservoir modeling, well logging and etc.) and the enhanced seismic acquisition (MAZ/WAZ) will also help.

Acknowledgements

We would like to thank Thang Long JOC and CGGVerias for permissions to publish this paper.

We would also like to thank Jason Sun, Xie Yi, James Sun and Don Pham for their valuable input to this paper.

References


