

P306

Seismic Velocity Anisotropy in the Illizi Basin of Eastern Algeria

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SUMMARY

The Tiguentourine field is located in the southern part of the Illizi Basin in eastern Algeria and is operated by the In Amenas Association, a joint venture between BP, Sonatrach and Statoil. Ordovician-aged hydrocarbon reservoirs in the Illizi Basin consist predominantly of tight clastic rocks with a complex depositional history. Production data suggests that open fractures may play an important role in determining individual well productivity. In 2004 a seismic acquisition and processing study was performed to investigate whether wide azimuth seismic data and subsequent azimuthal anisotropy analysis could provide information about fracturing in these tight reservoirs. A full-surface (non-sectored), azimuthally varying velocity analysis technique was used to measure the azimuthal velocity anisotropy. Results indicate highly variable azimuthal velocity anisotropy throughout the area and within the reservoir zone. If the seismic anisotropy can be related to lateral variations in fracture orientation and density, then well productivity could be maximized by drilling wells to intersect major fracture networks.

Introduction

The Tiguentourine field is located in the southern part of the Illizi Basin of eastern Algeria and is operated by the In Amenas Association, a joint venture between BP, Sonatrach and Statoil. Local structure is relatively simple with geologic dip in the 0 to 5 degree range, except near the NW dipping faults. On the other hand, the Cambro-Ordovician stratigraphy is relatively complex with erosional and depositional episodes of fluvial, marine and glacial environments resulting in relatively tight discontinuous clastic hydrocarbon reservoirs. Anomalous productivity from certain wells within the area suggests that open fractures may play an important role in enhancing permeability. A wide azimuth 3D seismic survey was acquired in an attempt to determine the degree of seismic velocity anisotropy present in the study area. If significant seismic velocity anisotropy exists and can be related to lateral variations in fracture orientation and density, then the exploitation of these fracture networks can add significant value.

Azimuthal velocity anisotropy

Grechka and Tsvankin (1998) showed that the azimuthal variation of NMO velocity is an ellipse in the horizontal plane, irrespective of the type or degree of intrinsic anisotropy. For instance, for VTI anisotropy, the NMO ellipse will degenerate into a circle, with no azimuthal variation. However, if the rock is then tilted (TTI or HTI for a 90° tilt) the azimuthal variation in NMO velocity will be described by an ellipse. The elliptical variation also holds for more complex symmetries, such as orthorhombic and triclinic media. Azimuthal anisotropy can have a profound effect on the seismic data (Williams et al, 2002; Lynn 2004) and can be attributed to complex fracturing differential horizontal stresses, or any mechanism that results in a rock fabric that is “stiffer” in one horizontal direction than another. A single set of vertically oriented fractures (open and fluid filled) is a simple mechanism to create an azimuthally anisotropic medium in which the velocities are faster parallel to the fractures (V_{fast}) than perpendicular to them (V_{slow}) - resulting in an azimuthally varying velocity field (Figure 1).

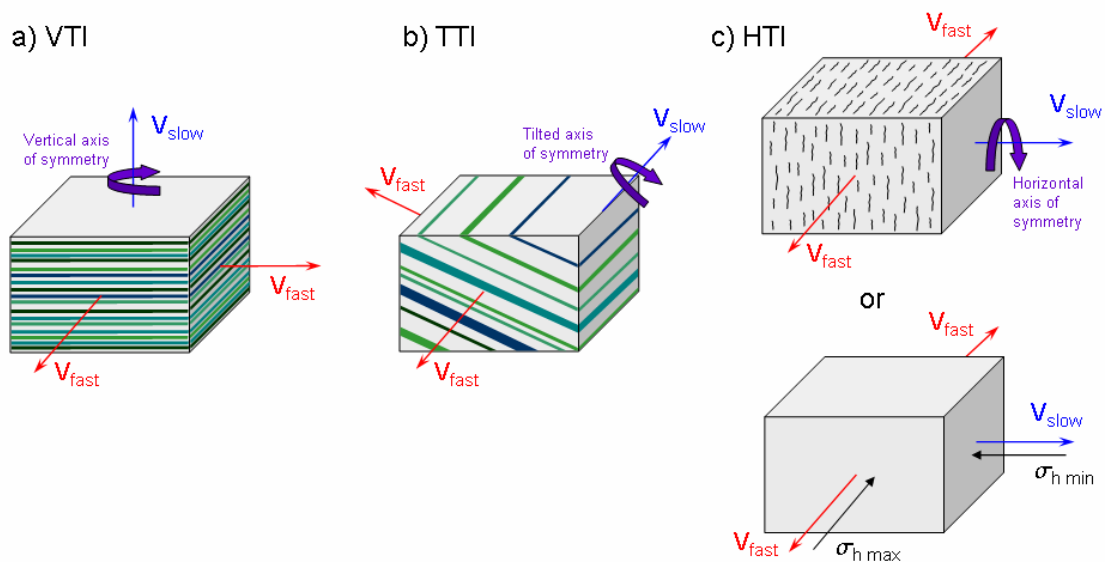


Figure 1. Various Types of Anisotropy

To see how HTI affects seismic data, consider a wide azimuth CMP super gather from the Tiguentourine area after isotropic NMO correction (Figure 2). Note the apparent reflector degradation with offset. If the far offset traces are resorted by azimuth, the apparent reflector degradation is seen as a set of time shifts associated with changing velocity with azimuth. As previously mentioned, geologic dip can have a similar azimuthal time shift signature, but the

effect is typically much less when comparing degrees of dip with percent anisotropy. In general, for dips less than about 10 degrees, the anisotropy effect should dominate.

Survey design and processing

In order to facilitate the measurement of azimuthal velocity anisotropy it is necessary to acquire wide azimuth 3D seismic data with a relatively complete sampling of source-receiver azimuths and offsets fully populated in each azimuth range. In 2004, a wide azimuth test survey was designed and acquired in the Tiguentourine area with this purpose in mind. The test survey had an improved offset and azimuth distribution relative to the previous narrow azimuth survey (2000).

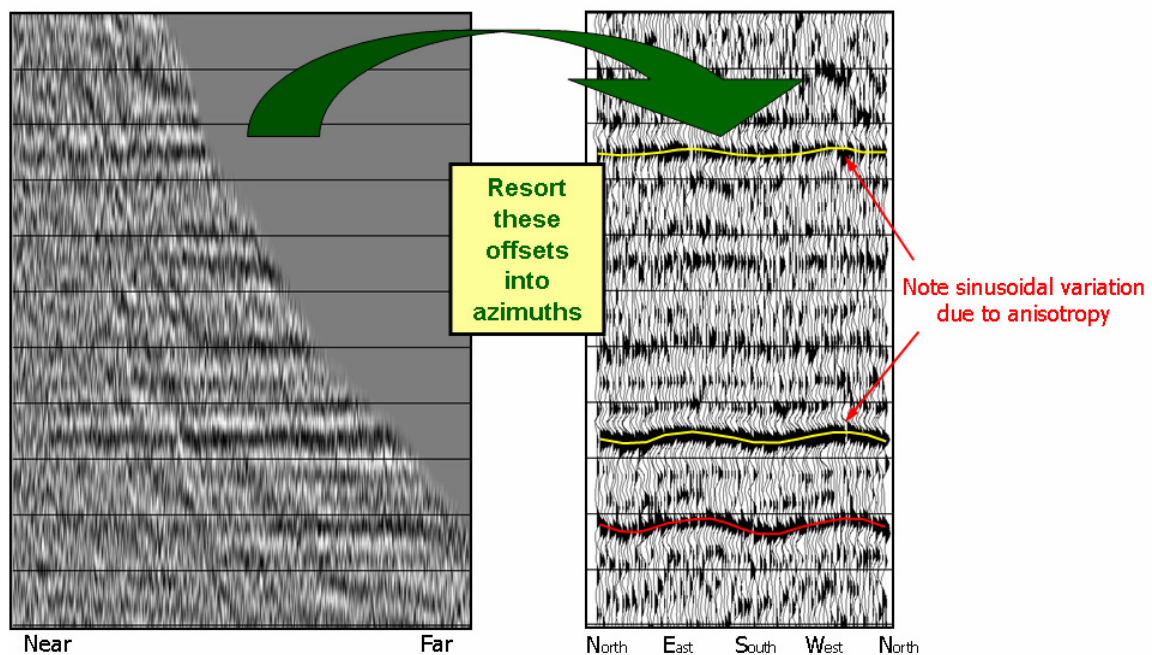


Figure 2. Effect of HTI on seismic data: (left) offset sorted CMP super gather after isotropic NMO correction; (right) azimuth sorted CMP super gather after isotropic NMO correction (Example from Tiguentourine field).

In three dimensions (x, y and time), reflection travel times in an isotropic medium create a hyperboloid with circular cross-section – the velocity being the same in all horizontal directions. On the other hand, for an HTI medium, reflection travel times create a hyperboloid with elliptical cross-section – with a fast and slow direction. By utilizing a full surface (non-sectored), azimuthally varying velocity analysis technique it is possible to measure and correct for the HTI effects (e.g. azimuthally varying velocity), as well as, create a suite of anisotropy-related attributes which can often be used to predict stress directions and/or fracture density and orientation (Figure 3).

Results

Figure 4 shows azimuthally sorted gathers from twelve monitor locations within the survey area. These gathers are all from areas of low geologic dip (< 5 degrees). Note the highly variable azimuthal velocity anisotropy throughout the survey area. In addition, at several monitor locations the anisotropy is isolated to the reservoir interval (e.g. yellow to red horizons). The anisotropy may be the result of differential horizontal stresses, vertical fracturing, or both. If the anisotropy can be related to the presence of vertical fracturing, then it may be possible to use this information to optimize well paths (and performance) by designing wells to intersect major fracture networks.

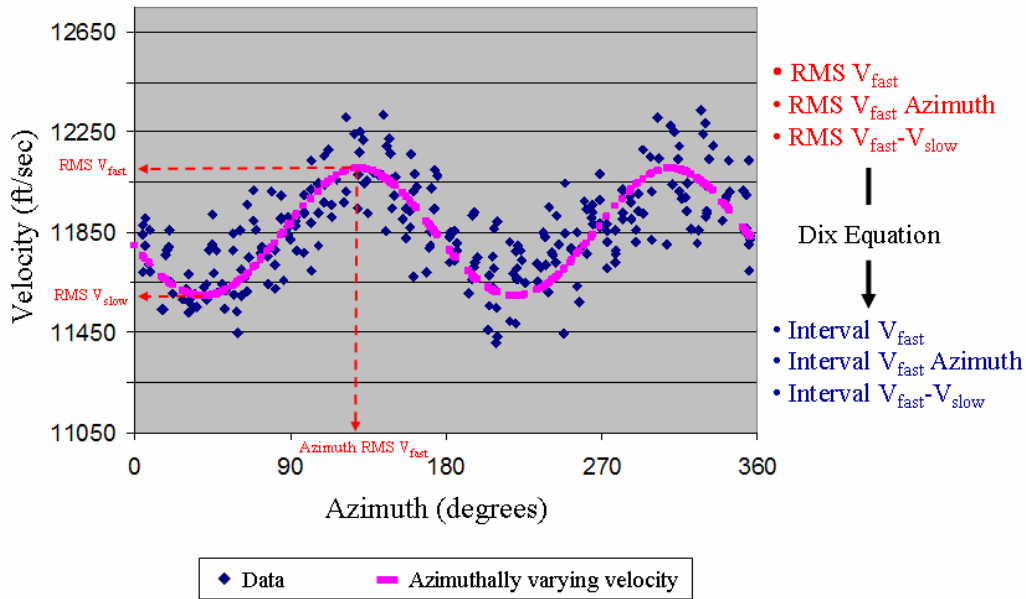


Figure 3. Velocity anisotropy attributes for a given analysis time and CMP super gather using a full-surface azimuthally varying velocity analysis technique (Example from Tigentourine field).

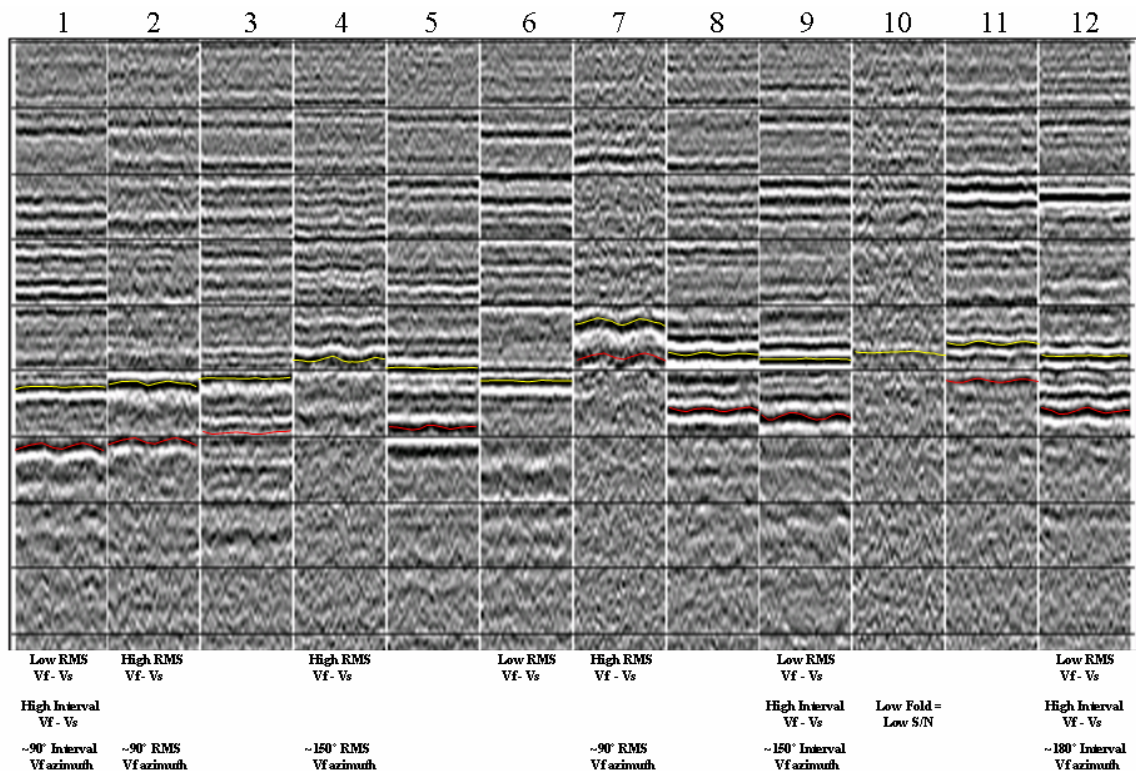


Figure 4. Azimuth sorted gathers (0° to 360°) for monitor locations.

Figure 5 shows an example of one of the velocity anisotropy attributes obtained from the full surface azimuthally varying velocity analysis technique. Note the lateral variation in Interval $V_{fast} - V_{slow}$ within the reservoir interval. If the anisotropy present can be related to fracture orientation and density within the reservoir interval, then well productivity could be enhanced by positioning wells to intersect major fracture networks.

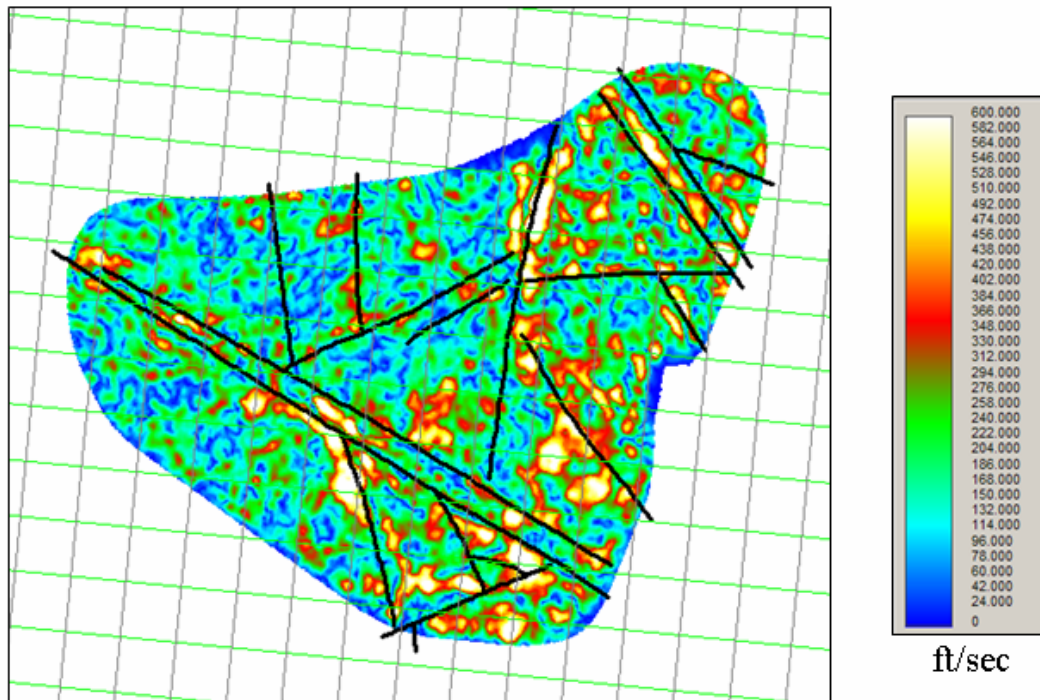


Figure 5. Horizon slice of interval $V_{fast} - V_{slow}$ velocity anisotropy attribute.

Conclusions

Reservoirs in the Tiguentourine field of the Illizi Basin in SE Algeria are complex, consisting of predominantly tight discontinuous clastic rocks. Production data suggests that open fractures may play an important role in well productivity. Wide azimuth 3D seismic data, combined with a full surface (non-sectored), azimuthal velocity analysis technique, indicate highly variable azimuthal velocity anisotropy throughout the area and within the reservoir zone. A feasibility study to determine whether the anisotropy can be related to fracture orientation and density is ongoing.

Acknowledgements

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