Full Azimuthal Orthorhombic PSDM- a Case study from Rajasthan Onshore Field

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Summary

Cairn Oil & Gas has recently completed an Orthorhombic PreSDM project from Rajasthan onshore data, Block RJ-ON-90/1. The objective was to implement Full Azimuth Orthorhombic Imaging of recently acquired wide azimuth 3D seismic survey data over Raageshwari Deep Gas (RDG) field. The study focused on improving the imaging for better understanding of Reservoir Quality and natural fractures to support the optimal field development.

Introduction

Raageshwari Deep Gas (RDG) field is situated in the southern part of onshore Barmer Basin in Rajasthan;

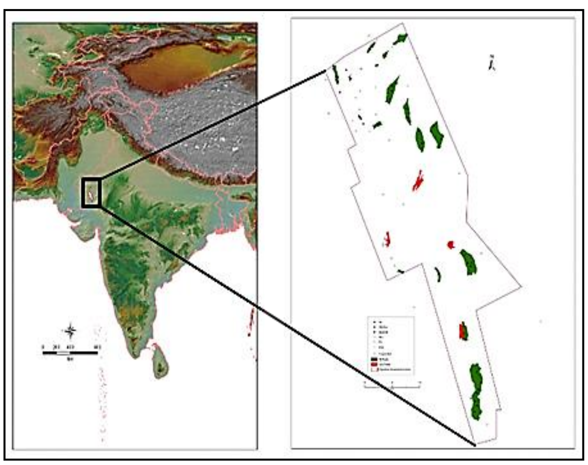


Figure 1: Left panel - location map of the Barmer Basin, Rajasthan, India. Right panel – location of the different fields (Green: Oil Fields, Red: Gas Fields).

RDG field contains a tight gas condensate reservoir, with excellent gas quality. Stratigraphically, the reservoir is composed of clastics of the Fatehgarh Formation overlying a volcanic complex comprising basic lava flows (basalts) and stacked silicic pyroclastic flows (felsics) interbedded with another older generation of basalts.

RDG tight reservoirs are characterized by low permeability, and hydraulic fracturing is required to create pathway for fluid flow, such induced fractures interact with natural fractures so that understanding of distribution, intensity and orientation of natural fractures is required for optimal design of hydro fracturing program. As an accurate orthorhombic velocity model is crucial for delineating the associated anisotropic parameters, PSDM processing was carried out using OVT tile based orthorhombic velocities with the processing objectives.

Transverse Isotropy manifests the effective role of anisotropy modeling in depth imaging over the last decade, however at areas characterized by tectonic stress and heavy fractures, Transverse Isotropy -which assume symmetry axis perpendicular to bedding- is not capable to model slowness in velocity across fractures beside slowness across layers.

Orthorhombic media have three mutually orthogonal planes of mirror symmetry (Tsvankin, 1997) is giving better understanding of fractures direction and cope with azimuthal velocity variation in these complex geological setting. figure 2 shows comparison between Tilted Traverse Isotropic medium (a) with one symmetry axis defined by dip (θ), and azimuth (φ) vs. Tilted orthorhombic medium (b) with three symmetry plains are defined by Euler ψ, θ, and φ model-driven attenuation and anisotropy compensation during imaging.

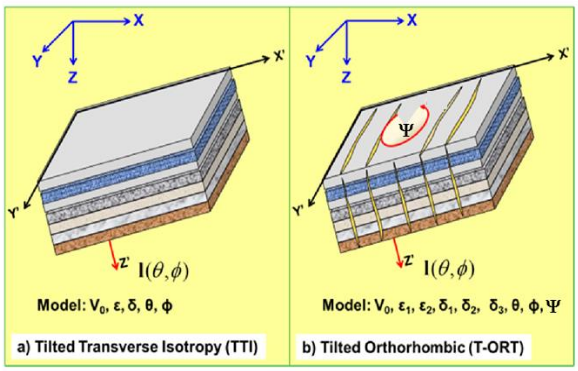


Figure 2 Comparison of TTI and Tilted Orthorhombic media
(Yunfeng Li 2012)

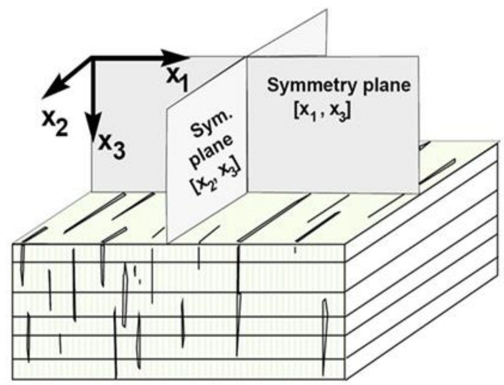


Figure 3 Orthorhombic symmetry planes
(Grechka and Tsvankin 2011).

In orthorhombic model building we expect the velocity to be faster parallel to bedding and we also expect velocity to be faster parallel to fractures. Anisotropy varies through more than one plane. We get 5 new parameters: Following figure 3 shows the orthorhombic symmetric planes

ε_2 — The parameter ε in the symmetry plane ***[x1, x3]*** normal to the x2-axis

δ_2 — The parameter δ in the ***[x1, x3]*** plane responsible for near-vertical P-wave velocity variations,

ε_1 — The parameter ε in the **[x2, x3]** plane

δ_1—the parameter δ in the ***[x2, x3]*** plane

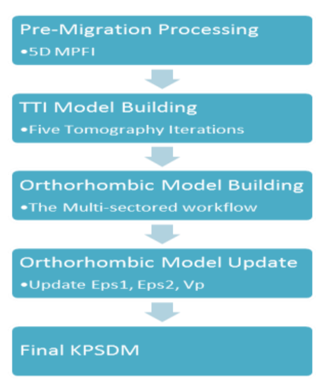
δ_3 —the parameter δ in the ***[x1, x2]*** plane

VTI case can be considered a special case of Orthorhombic where

$\varepsilon_1 = \varepsilon_2 = \varepsilon$ and $\delta_1 = \delta_2 = \delta$

Methodology and Workflow:

During this PSDM processing we have implemented the Multi-sectored workflow estimates the quadratic form by using the TTI models generated from tomography runs at different azimuths. The process involves running CIP tomography on azimuth-limited data to produce separate models for each azimuth sector that describes the anisotropy along the azimuth of those sectors as shown in Figure 4,5 and 6. These models are then input to the Orthorhombic Sectored workflow plugin which derives a single orthorhombic model that is appropriate for all azimuth sectors. This initial estimate of the initial orthorhombic velocity model can be described as a least squares problem where we describe a best fit orthorhombic model that explains the variation we see in each azimuth.



Workflow Implemented

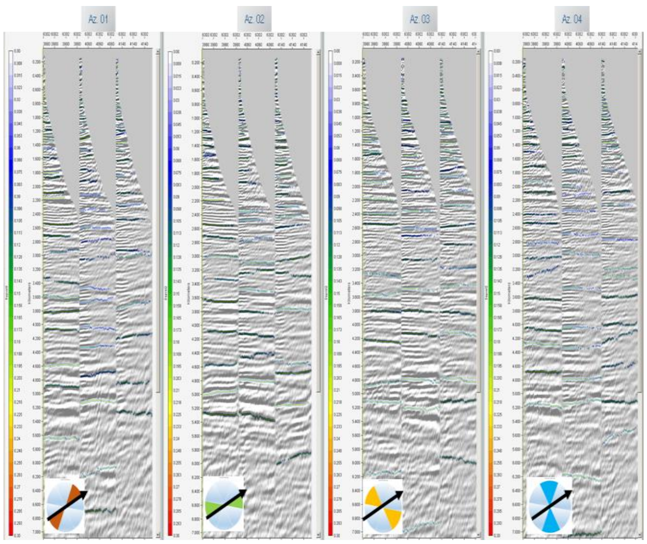


Figure 4. Different azimuthal sector gathers to generate anisotropic parameters along different symmetric axis

Delta

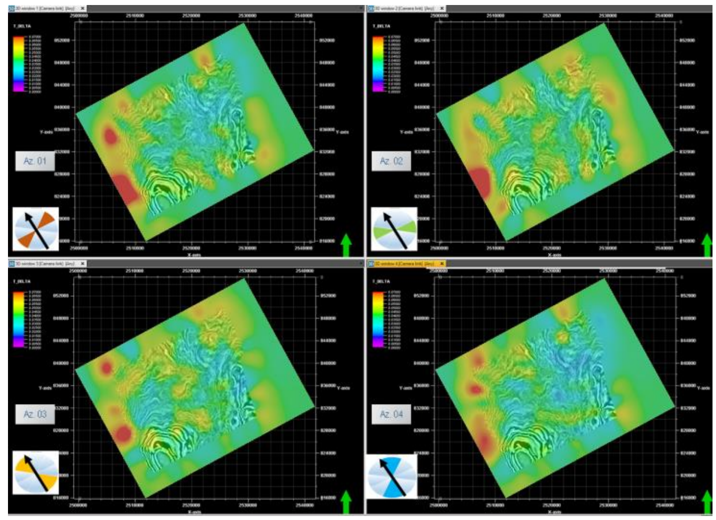


Figure 6. Anisotropic parameter Delta along different Azimuth directions

Epsilon

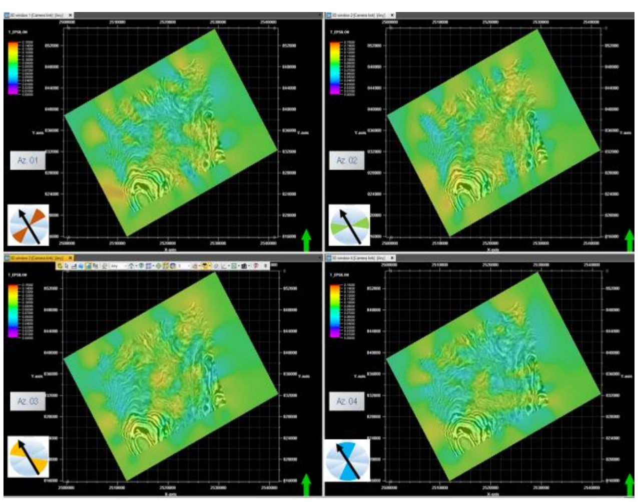


Figure 5. Anisotropic parameter Epsilon along different Azimuth directions

Orthorhombic Parameters

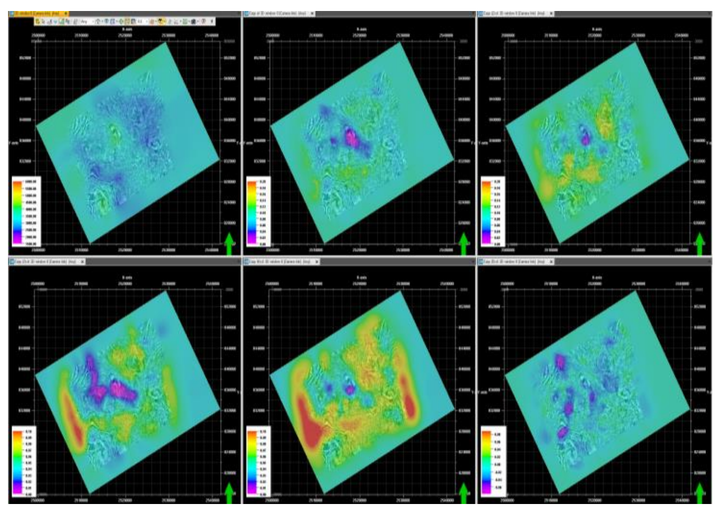


Figure 7. Orthorhombic parameters along different symmetric planes (Vp, Epsilon1, Epsilon2, Delta1, Delta2 and Delta3)

Results:

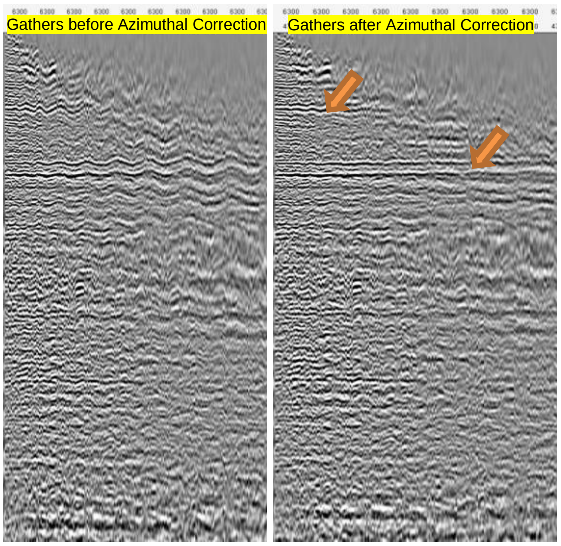


Figure8. Comparisons of Common offset and common azimuth (COCA) Gathers before and after Tilted Orthorhombic PSDM.. Orthorhombic PSDM approach managed to account for anisotropy in different symmetrical axis to solve the effect of azimuthal variations in gathers.

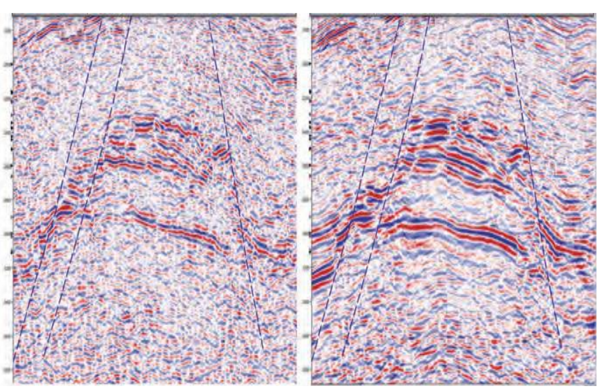


Figure 9 Comparison of vintage and current seismic Data quality: Left: vintage seismic and Right: new Full Azimuthal PSDM seismic, showing enhanced image quality.

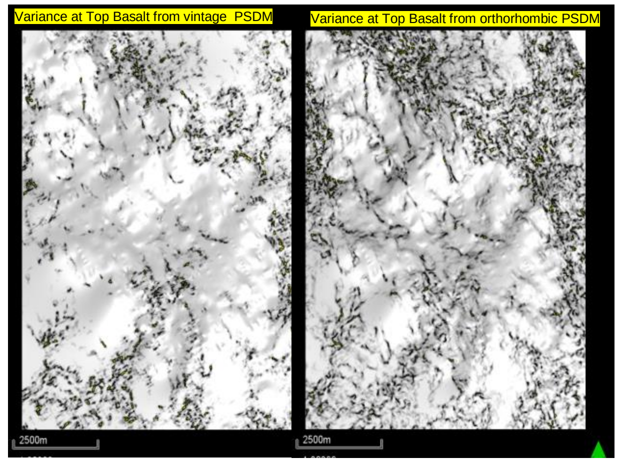


Figure 10 Variance map showing better fault/fracture characterization using Orthorhombic PSDM data at Top Basalt Horizon

Conclusions

In general Transverse Isotropy is not capable to solve azimuthal imaging problems; Orthorhombic PSDM is very effective in getting better faults definition and structure alignment, in comparison to VTI/TTI imaging.

Here we have implemented the orthorhombic PSDM approach for model building and managed to account for anisotropy in different symmetrical axis to solve the effect of azimuthal variations.

This study helps the interpreters for better understanding of fracture network in this area.

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Fracture detection and calibration in a tight Volcanic gas reservoir, Barmer Basin, India Sreedurga Somasundaram, First Break

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