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P431

Syn-drill Seismic Imaging through Seismic Guided Drilling A Case history from East coast India deep water example

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Summary

Krishna Godavari basin is a continental passive margin peri-cratonic proven petroliferous basin located in the east coast of India, containing thick sediments of more than 5 Km with several cycles of deposition, ranging from Late Carboniferous to Pleistocene.

The cretaceous syn-rift plays have been the attention of exploration in recent times in offshore area. The discovery hydrocarbons in syn-rift/cretaceous sediments necessitated improvement in the seismic imaging of the cretaceous/rift fill sediments. These syn-rift plays are in HP-HT environment. In order to get good depth control, porepressure prediction for safe and successful drilling of HP-HT wells, Seismic Guided Drilling(SGD) was carried out in Krishna Godavari(KG) basin. In order to explore the potential of series of cretaceous/syn-rift sediments in a horst-graben complex,recently one of the well was drilled in G-4-6 area where SGD technique was used for having control/confidence while drillingand pore-pressure and syn-drill imaging.

Keywords: *Seismic Guided Drilling, HP-HT well, Cretaceous sediments*

Introduction

Study is pertaining to Krishna Godavari basin which is a continental passive margin peri-cratonic, petroliferous basin located in the east coast of India, containing thick sediments of around 5 Kms with several cycles of deposition, ranging from Late Carboniferous to Pleistocene.

KG basincame into existence after rifting along eastern continental margin of Indian Craton in early Mesozoic. The faults stretching to basement define the series of horst and graben features cascading down towards the ocean and are aligned NE-SW along Eastern Ghat trend of pre-cambrian age.

The basin has proven to be potential target for hydrocarbon exploration from oldest Gondwana to recent pliestocene sediments.

The cretaceous sediments are gaining attention and importance in the offshore part for their hydrocarbon potential. The challenge of exploring the sediments is their HP-HT environment.

SGD technique was adopted as an aid to drill the well safely and successfully and improving seismic imaging through HP-HT environment. The main target in the well was the cretaceous/ syn-rift sediments.

Well under discussion is an exploration well (HP/HT) and located in Krishna-Godavari basin.
Description
Target 1: Mainly sandstone with minor shale; Primary target
Target 2: Sandstone; Secondary target
Target 3: Sandstone – Secondary target

Methodology

Seismic Guided Drilling (SGD) Phases:

SGD project is carried out in three (3) phases:

- Feasibility Study;
- Pre-Drill Baseline;
- Syn-Drill SGD updates.

The Feasibility phase involves checking all the available data, assessing any data gaps to be filledand

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recommending measurements while drilling to fill the gaps, and performing forward modeling if time permits, to help designing the baseline plan.

The baseline phase includes the integration of all measurements available into new model through pre-stack depth imaging, interpretation, seismic inversion, lithology estimates along with pore pressure estimates based on the arrived model. All setups, flows, models etc. prepared are for application in syn-drill updates.

The syn-drill phase includes the update of the earth model while drilling, using SVWD measurements, and all available measurements and delivery of the updated earth model andetc. for taking drilling decisions.

Each phase of the project builds on understanding the earth model and ensures that allavailable information is incorporated to improve its accuracy and to reduce the sub surface uncertainty. It also helps to ensure that appropriate workflows are selected to address thespecific challenges of theenvironment under consideration.

Data Availability

The SGDimplementation and updates during drilling covered an area of 25 Sqkm of 3D seismic cube (5 x 5). The seismic data is processed to Anisotropic Pre-Stack Depth Migration (APreSDM). The study area is a subset of the legacy 3D seismic volume covering the entire area under study.

Baseline summary

- Depth prognoses changed with Revised T-D from RPGMIG SGD baseline shows changes.
- A NW shift of Early Cretaceouswedge is indicated in Revised maps due to velocity variation andanisotropy effects.
- SGD pore pressure showed two PP ramps, one corresponding to the top of Mioceneand the other corresponding to the top of Cretaceous The deeperramp corresponds to a very narrow drilling window which may be by the largepressure increase in Cretaceous formation below and by the estimated low fg on topof Cretaceous due to high velocity and low Poisson’s ratio.

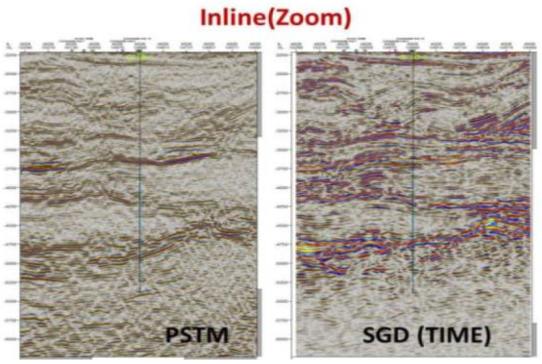

Fig-1: Comparison between initial PSTM and SGD Baseline processed section.

Update-1Summary

Two updates were made for pore pressure and fracture gradients estimation based on thecurrent drilling information.

Both updates are consistent with the drilling MW, MDT, and LOT, also with improved rockmodels.

Update-2 Summary

SVWD checkshots were received upto 3048m TVD during realtime update2.

ExistingUpdate1 velocity model was calibrated using this checkshot information and tomography iterations were run for updating the velocity model. Pre-stack depth migratedgathers and image stacks were produced and checked to verify the model. Later the model was used to generate the products.

Logs up to 3210 m (within deviated hole) were used in addition to the available data forthe update-2 inversion.

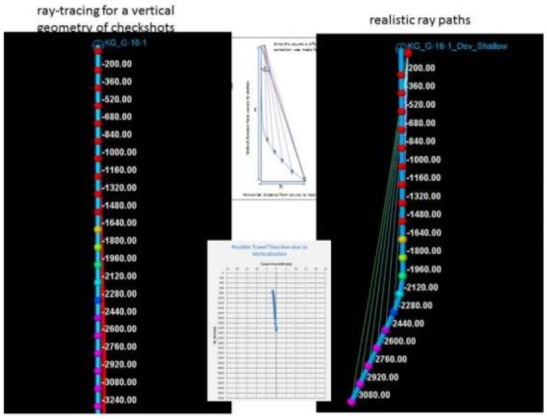

Fig-2: Corrections for raypaths even smaller in magnitude, were applied to maintain accuracy in imaging.

Update-3 Summary

- Pore pressure gradient, fracture gradient, and overburden gradient are estimated based onVp fromupdate 3.

- The update 3 pore pressure shows a retained gradient and larger window for the sectionbelow compared to the earlier estimations.

- Lithology classification shows increase in sand layers in Cretaceous, Uncertainty for lithology estimation is high due to lack of statistics and lack of separation inrock property.

- Current TD just crossed the Cretaceous top.

- Unexpected low velocity zone appeared. This low velocity zone may correspond to significant PP increase comparing to the RT 2Result.

- RT 3 Tomo update puts a high velocity trend in the Early Cretaceous sand (around 3200 m/s).

- Cretaceous top is observed moving up about 50 m with lateral shift of the major target, Early Cretaceous.

Update-4 Summary

Early Cretaceous top High velocity was intend to correspond to significant PP decreasecomparing to the RT 3 result RT 4 Tomo update puts a high velocity trend in this zone(around 4000 m/s).

As a result, Early Cretaceous horizon top is seen moving down about 100m.

Pressure below the basement is highly uncertaindue to lack of resolution of seismic velocity and the rock model is not valid at that level. The PPP forupdate 4 used “shale” trend for pressure estimation, assuming the hard basaltic, siltstonesare in equilibrium with the shale background.

Final Update summary

The periodic updates i.e. up to four updates ensured the pore-pressure predictions and depth control which allowed safe drilling of the well with the seismic image updates. Further as the logs and velocity updates were available, elastic inversion was performed by incorporating final velocity model, image stack,conditioned logs and other relevant drilling information. A mild RAAC was applied to the depthdomain seismic gathers to balance the seismic amplitude against depth. Non-rigid matching (NRM)was applied to the migrated seismic gathers to warrant for the flatness of the seismic gathers.

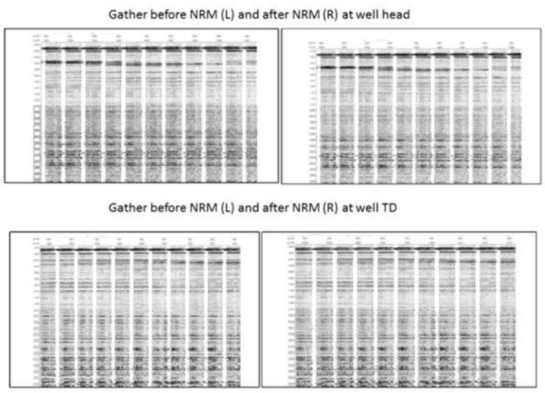

Fig-3: Gathers before and after NRM at well head and TD

The flat gathers with proper rock physics based velocities ensured good and proper stack for better seismic image and thereby the updated structure maps.

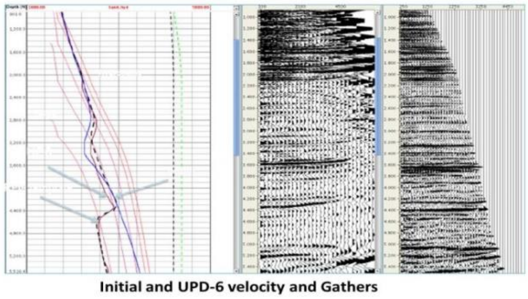

Fig-4: Initial and final velocity and gathers display.

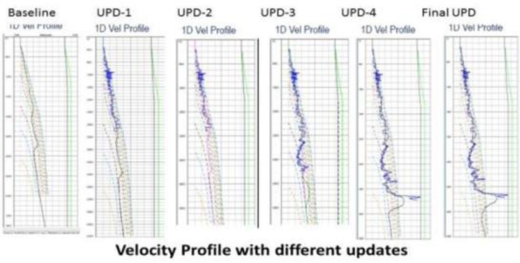

Fig-5: Display of velocity profiles with different updates.

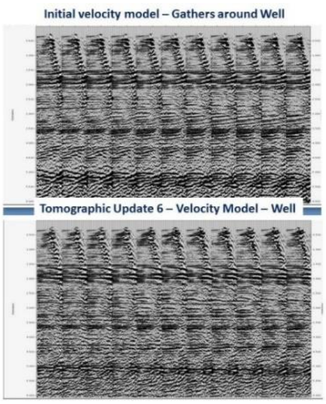

Fig: Initial and final velocity model : gather updates

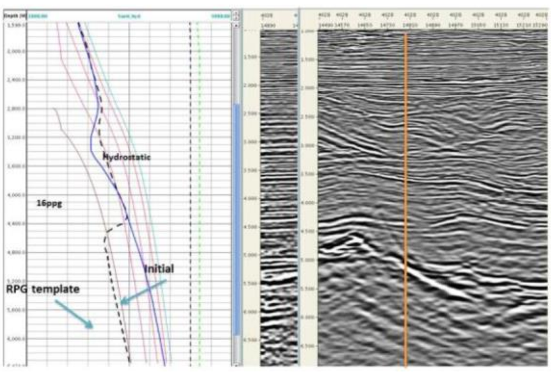

Fig-6: Velocity, Gather, Stack at well location:Initial

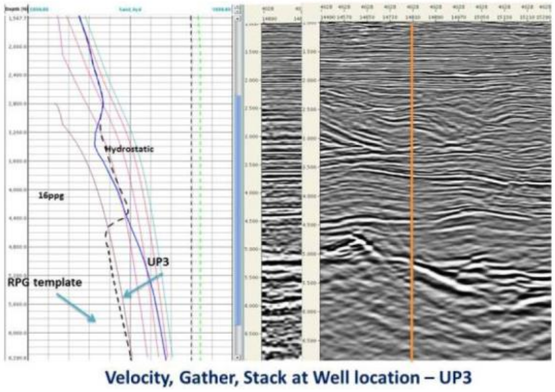

Fig-7: Velocity, Gather, Stack at well location: Update-3

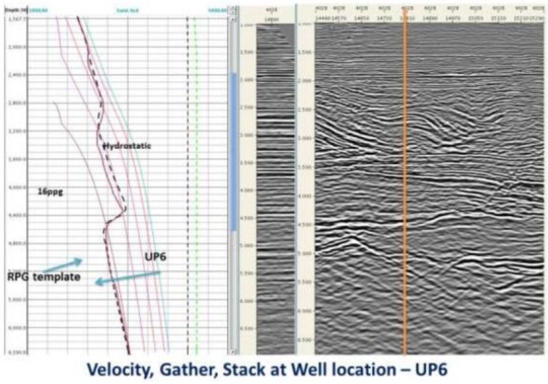

Fig-8: Velocity, Gather, Stack at well location: Update-6

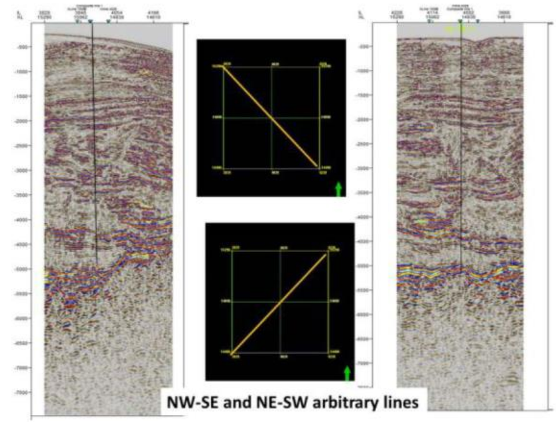

Fig-9: NW-SE and NE-SW arbitrary lines

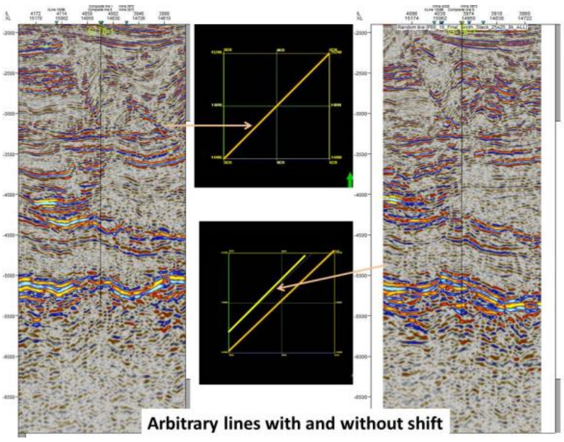

Fig-10: Arbitrary lines with and without shift

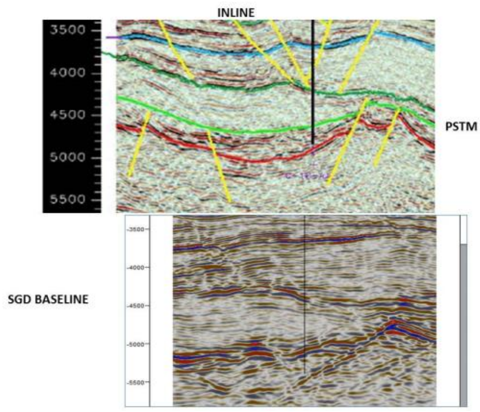

Fig-11: Seismic section PSTM and SGD baseline

Discussion and Conclusion

Seismic Guided Drilling* (SGD) service for well in G-4-6area is the first application of SGD in high temperature and high pressure (HTHP) well which extended the RPGMIG*concept to HTHP environment. RPGMIG technology in SGD helped define better image in depth within the volume of interest (VOI) and a common and shared earth model (same earth model for both Imaging and beyond Imaging).

In SGD baseline work, shallow hazard zone was identified. SGD baseline imaging indicated not only an overall shallow-up in structure but a substantial lateral shift in the location of the main deep target that led to the change of the well trajectory.

Four real time updates carried out while drilling phase and a final update was performed after drilling.

High Quality SGD imaging provided accurate 3D image which successfully guided thedrill bit to tap the major targets in the Cretaceous that suggeste3d shift from the legacyimaging volume.

SGD pore pressure prediction revealed multiple high pressure ramps with enoughaccuracy that helped the drilling team in terms of proper casing and mud programs and ensured a safe and successful drilling completion.

SGD updates while drilling reduced the prediction uncertainty which showed significant impact onthe drilling in real time.

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