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Optimizing Acquisition Geometry to Improve Sub-Surface Image Using Modeling Studies – Case Study from Krishna-Godavari Basin, India

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Summary

The KG Basin in the East coast of India is a passive margin basin which belongs to a unique poly cyclic extensional province. Geologically the basin exhibits a very complex sub-surface picture, especially in the west Godavari sub-basin area. The sub-surface imaging becomes a challenge because of the thick basaltic layer at the shallow level in this part of the basin. The basaltic layer varies in thickness from 50 m to 160 m with depth of 500 m to 1500 m in this part of the basin. Many 2-D, 3-D and a long offset seismic campaigns were conducted in this area. But clear & unique picture of the sub-surface, comprising of the basement, basement related faults, thin lenticular sands within the older sediments below the basalts etc., could not be seen so far. A model based approach was attempted to optimize some of the parameters like far offset requirement, type of shooting geometry etc. to facilitate better imaging of the sub-surface.

A geological model was prepared and digitized. Various geometries were used with different far offsets and ray tracing was done to see illumination of the sub-surface. Synthetic data was generated using various geometries and the synthetic seismic data was processed as 2-D lines and the results were compared.

Introduction

Krishna-Godavari Basin : The K-G Basin in the East coast of India, is a passive margin basin which belongs to a unique poly cyclic extensional province. The Basin consists of two parts - the peri-cratonic passive margin superimposed on the orthogonal Pranhita Godavari basin.

The origin of the basin is related to three stages of rifting. The Proterozoic Proto-rift (NW-SE) accommodated the Purana group of sediments. Thereafter the Gondwana rifting followed and superimposed on the Proterozoic graben and accommodated the Gondwana group of sediments. The final rifting (NE-SW) took place during the breakup of the Gondwana land and was followed by drifting of the separated part of the Gondwana land. The drifting was also accompanied by south easterly tilting of the basin. This tilt is clearly manifested by the monoclinal dip of the basaltic flow towards the basin. The basaltic flow (Razole formation) is further affected by a fault system called the Matsyapuri- Palakollu fault which divides the basin into two distinct regimes for exploration. The target for exploration to the north of this fault are the pre-trappeans (Cretaceous and older) and to the south of it are the Post – trappeans (Paleogene & Neogene).

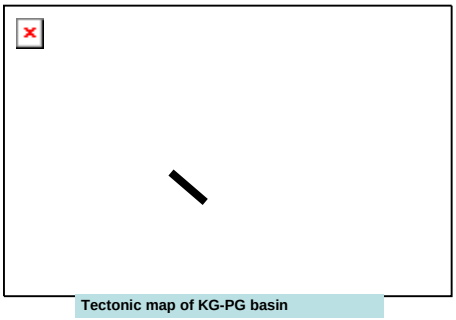

Figure 1: Tectonic map of KG-PG Basin. The dark line indicates the location of the geological model

Basin configuration : The basin is marked by three grabens – Krishna sub basin, West Godavari sub-basin and East Godavari sub – basin, separated by two horsts – Bapatla high & Bhimavaram-Tanuku high (Fig-1). The West Godavari sub-basin is further sub divided into Gudivada garben & Bantumilli graben separated by Kaza-kaikalur high. The basin displays a dispersed hydrocarbon habitat containing hydrocarbons at different stratigraphic levels ranging from oldest mandapeta Sand to the Youngest Godavari clay in the off-shore.

Imaging challenge

Geologically the basin exhibits a very complex sub-surface picture, especially in the West Godavari sub-basin area. The sub-surface imaging becomes a challenge because of the thick basaltic layer at the shallow level in this part of the basin. The basaltic layer varies in thickness from 50 m to 160 m with depth of 500 m to 1500 m in this part of the basin. Many 2-D, 3-D and long offset seismic campaigns were conducted in this area. But clear & unique picture of the sub-surface comprising of the basement, basement related faults, thin lenticular sands within the older sediments below the basalts etc. could not be mapped unambiguously so far.

Geological model : Based on the well data available along a dip line, a geological model was prepared. The basement related faults and the horizon trends were incorporated in the model based on the seismic sections of the area (Fig.2) .

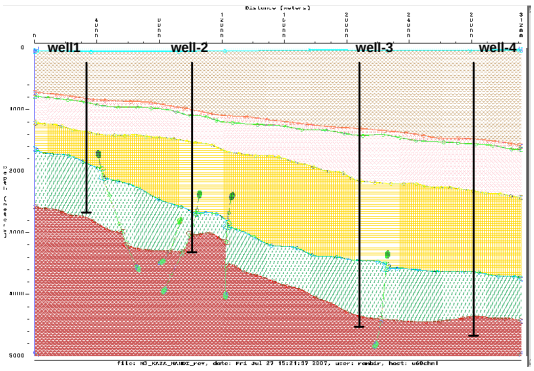

Figure 2: The digital model genertaed in computer using the geological model

Depth (m)	V int (m/s)	Vrms (m/s)	2-T (Seconds)	Xnmo (m)
0	2000	2000	0.00	0
53	2500	2480	0.05	72
1467	3750	2533	1.18	1643
1544	3000	2597	1.23	1743
1814	2800	2603	1.41	2004
1874	3000	2674	1.45	2121
2313	3500	2875	1.74	2741
3166	3750	2954	2.23	3606
3527	3900	3051	2.42	4045
3990	3700	3073	2.66	4475
4150	5000	3341	2.74	5023

Table-1 Computed travel times, Vrms & far offset for 30 % stretch mute

Modeling studies: The above geological depth model was used to generate the digital model. Based on the well data the two way travel times, Vrms & far offset requirement, considering 30 % stretch mute were computed as tabulated in Table-1. Ray tracing was done at strategic locations over the digital model for various shot-receiver arrangements and synthetic shot records were generated in 2-D mode (Fig-3,4) .

Ray tracing: Ray tracing was done using the following parameters:

Simulation : Reflection mode, Group interval 50 m
Wavelet : Ricker, 30 Hz
Sampling rate : 2 ms
Pass band : 8-72 Hz
Propagation: Reflection+Transmission + Spreading + Attenuation

End-on 6000 m offset

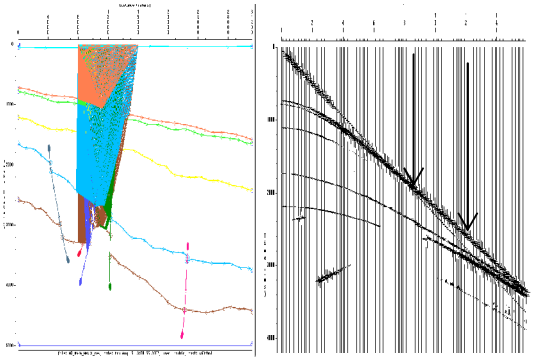

Figure 3: Synthetic shot record for end on , 6000m offset

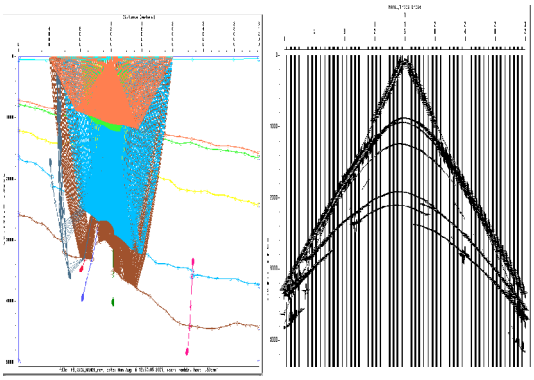

Figure 4: Synthetic shot record for sym.split spread , 8000m offset

Synthetic data : Synthetic seismic data was gathered using the geometries as out lined below :

1. Symmetric split spread with 160 channels, 4000m far offset, Group interval 50m, foldage 80
2. Symmetric split spread with 200 channels, 5000m far offset, Group interval 50m, foldage 100
3. Asymmetric split spread with 160 channels, 4500m + 3500 far offset, Group interval 50m, foldage 80
4. Asymmetric split spread with 160 channels, 5000m + 3000m far offset, Group interval 50m, foldage 80

A percentage of random noise was added to the synthetic data to include the field effects of real data. The data was processed & Synthetic seismic sections were generated for the different geometries and compared (Fig -5 to 10).

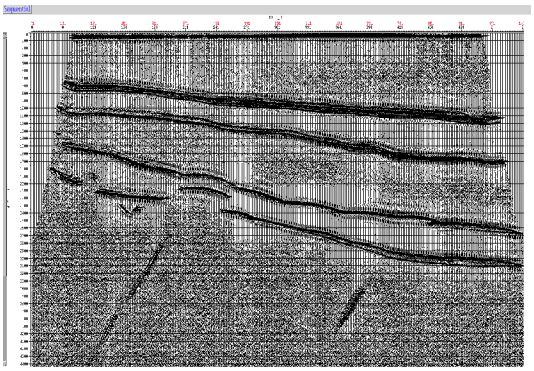

Figure 5: Syn,stack – sym.split spread- 4000m far offset, 80 fold data

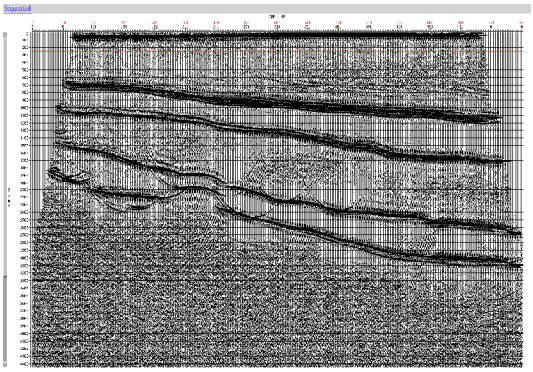

Figure 6: Syn,stack – Migrated - sym.split spread- 4000m far offset, 80 fold data

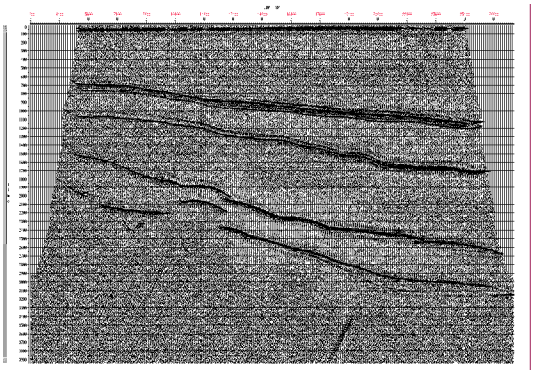

Figure 7: Syn,stack – sym.split spread- 5000 m far offset, 80 fold data

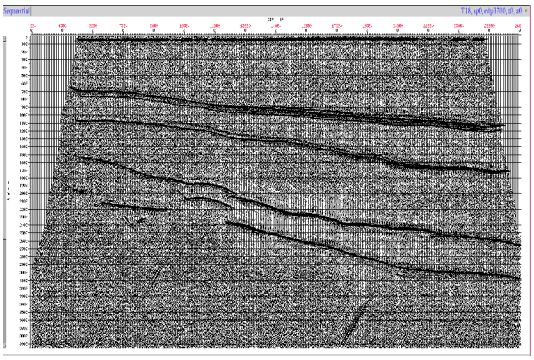

Figure 8: Syn,stack –Assym.split spread- 4500n + 3500 m far offset, 80 fold data

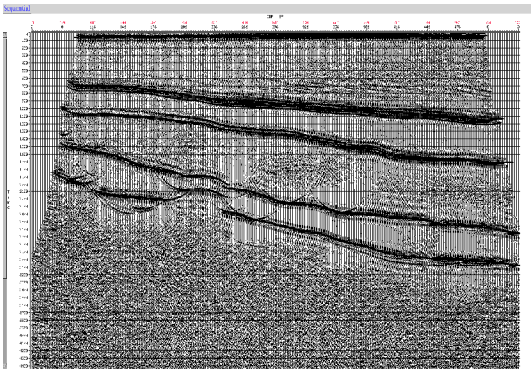

Figure 9: Syn,stack –Assym.split spread- 4500n + 3500 m far offset, 80 fold data – Migrated

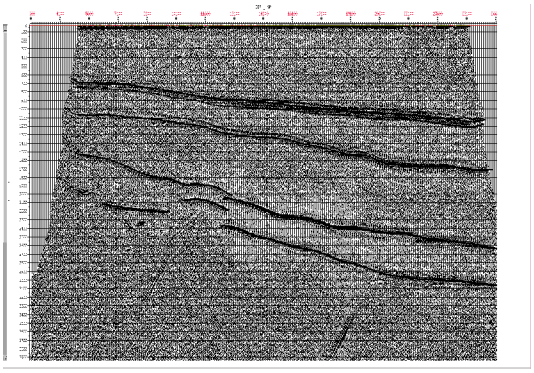

Figure 10: Syn,stack –Assym.split spread- 5000n + 3000 m far offset, 80 fold data

Observations & Discussion: It is observed that the synthetic stack sections acquired with the four different geometries with various far offsets are identical . The basement along with the faults are imaged correctly. When the comparison is made with the real seismic data the lack of continuity & consistency becomes apparent. This could be partially attributed to the adverse effect of the basalt layer. Because of the sharp velocity contrast at the top of the basalt, most of the impinging energy is reflected back, making the energy transmitted downwards, weaker which is further weakened at the other interfaces. Further complications are brought in because of absorption & scattering within the basalt, refraction along the basalt top, multiples between the basalt & the low velocity near surface layers and interference between direct arrivals & the reflected arrivals from deeper zones at far offsets. Another adverse dimension is added to the field efforts, due to the logistic challenges & intense cultural activities / noise.

Conclusions

The modeling studies indicate that the far offsets do not play a crucial role in sub-surface imaging in West Godavari basin. This could be because of the gentle, monoclinal dips (10-15 Degrees) in this area in contrast with the complex geology involving thrust & fold belts. Far offset requirement, for the deepest reflector (Basement), calculated for a 30 % stretch factor which falls in the range of 4500m to 5000m, seems to be optimum in this area.

Asymetric split spread is preferable for focusing shallow & deeper zones of interest. Broader dynamic range recording systems coupled with higher foldage data will compensate for the low energy penetration, poor signal to noise ratio at the far offsets and loss of foldage due to logistic hurdles.

More emphasis on field efforts is needed to maintain good signal response from deeper zones, proper balanced trace distribution in the near, intermediate & far offset ranges, proper recovery plans for low fold zones due to logistic challenges. Digital sensors which can record data over a wider band-width, especially in the lower frequency side can also be useful in this area.

Processing efforts like Radon transform for multiple attenuation, Inverse Q-filtering, low frequency preserved / oriented processing etc. will compliment the field efforts to bring out the enhanced sub-surface image.

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