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Seismic Imaging of Deeper Objects in Krishna-Godavari Basin : Analysis of Crucial Issues

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Summary

Presence of Bhimanapalli limestone of middle Eocene age and basalts of early Paleocene age, in Krishna-Godavari basin, causes poor seismic energy penetration. This always results in an inadequate image of sub-surface corresponding to deeper formations. Long offset seismic data was acquired in Amalapuram block of KG basin for imaging of deeper objects. A 2D line from this data set was processed adopting different processing approaches. The study deals with various issues involved in imaging of deeper formations alongwith merits and demerits of various processing approaches and improvement observed.

Introduction

Krishna Godavari basin developed along the eastern coast of Indian peninsula covers mostly coastal tract of Andhra Pradesh. The basin presents a fully developed passive margin sequence in the northern part and is characterized by en-echelon interior features and sags in southern part. The entire passive margin sequence rests upon the eroded Permo-Triassic rift fill sequence.

The vast and thick sedimentary record of KG basin holds oil and gas at different stratigraphic horizons in the range of Triassic to Miocene. Seven petroleum systems have been identified belonging to five major tectonic episodes of this basin. Mandapeta sandstone, Kanukollu sandstone, Tirupati sandstone, Razole formation, Pasarlapudi formation and Ravva formation hold the major hydrocarbon bearing reservoirs in the basin.

Area of the present study falls in Amalapuram block of Godavari trough in KG basin (figure-1). The area is not yet well explored for deeper formations and no well information exists to confirm the presence of Lower Gondwana and Nizampatnam groups. However recent hydrocarbon strike in adjoining area, suggests the possible presence of hydrocarbon in post rift fills of lower cretaceous age, which are expected at a depth of more than 5 km. Coal-shale inerbeds of lower Gondwana and equivalent of Pennar and Gajulapadu shale may serve as source rock at deeper levels. Sandstones equivalent of Golapalle formation capped by Chintalapalli shale may act as potential reservoirs.

The area is characterized by the presence of hard fossiliferous Bhimanapalli limestone of middle Eocene age, deposited in an inner neritic regime at shallow levels and Razole formation consisting of dark grey basalt of early Paleocene age at deeper levels. Both these formations significantly reduce the seismic energy penetration and as a result, incoherent events are seen on seismic section corresponding to Cretaceous formations. With the objective to explore these deeper formations, long offset seismic data was acquired in the area. A 2D line from this data set was taken up to study the effectiveness of various processing approaches for deeper imaging in KG basin.

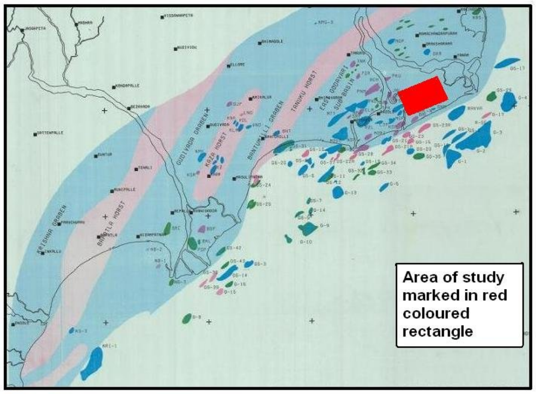

Figure-1: Map showing area of study

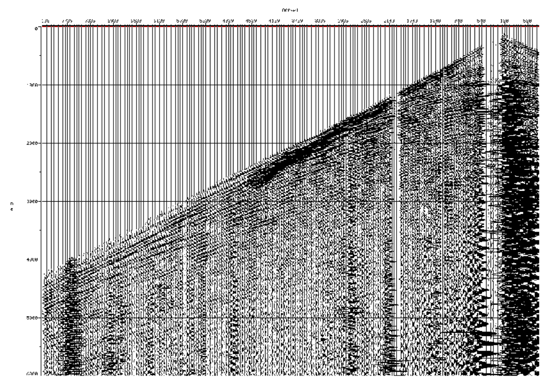

Figure-2: Part of representative shot gather

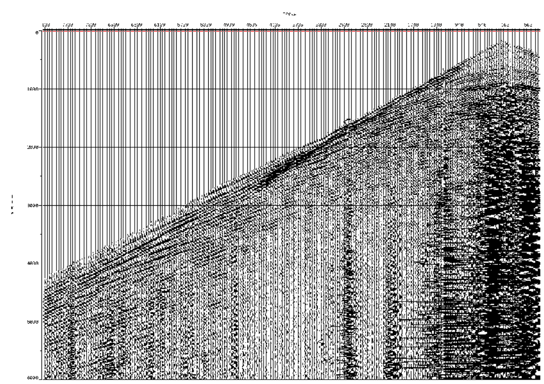

Figure-3: Shot gather after correction for hydrophone data

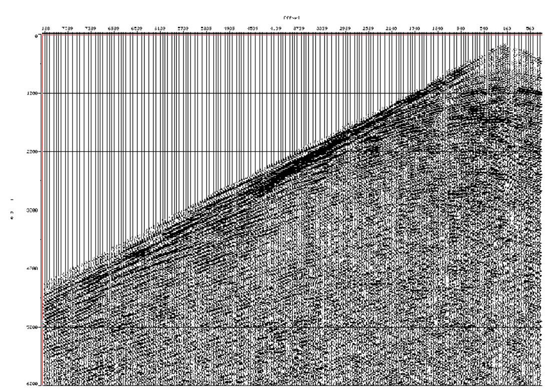

Figure-4: Final shot gather after signal conditioning

Input Data

Long offset 2D seismic data was acquired in the area using asymmetrical split spread (400+200 receiver channels) with record length of 10 seconds. Receivers were placed at an interval of 20 m and maximum offset in the spread was 8140 m. This is nearly 1.5 times the depth of expected target.

Because of the numerous drains present in the island block of Godavari river, it was not possible to plant geophones at many locations. Hydrophones were used in such patches to fill the data gaps. Figure-2 shows a part of representative shot gather with spherical divergence correction. Channels with weak energy in the offset range 200 to 500 m on this gather correspond to the zone occupied by hydrophones. Data is infested by strong ground roll and cultural noise in patches. However, overall quality of the data is good.

Signal Conditioning

Spherical divergence correction was applied after application of field statics and band pass filter. In many patches hydrophones were used which are accelerometers by function and have different energy pick in comparison to geophones. Traces recorded by hydrophones were integrated and a constant scalar was applied to bring them at par with geophone data. Representative shot gather with this correction is shown in figure-3.

A combination of different signal conditioning algorithms, applied judiciously, resulted in overall improvement of signal to noise ratio in the data (figure-4).

Role of Low Frequencies

Initially data was processed adopting conventional processing of DMO stack followed by FX migration. Band pass filter applied on the input gathers was 5-10-70-80 Hz. Migrated stack of the line is given in the figure-5. Basic processing sequence adopted for this data set is given in table-1.

Since amplitude decay of seismic signal with depth is a function of frequency, lower frequencies are less absorbed in the ground and capable of carrying deeper information. To study the effect of utilizing only lower frequencies, data was again processed restricting the frequency band of input gathers to 3-6-50-60 Hz. Migrated stack using lower frequency is given in figure-6. Although post stack processing including time variant filter is same, effect of restricting the frequency on input gathers has brought out a better image of events in the range of 4 to 5 sec two way time.

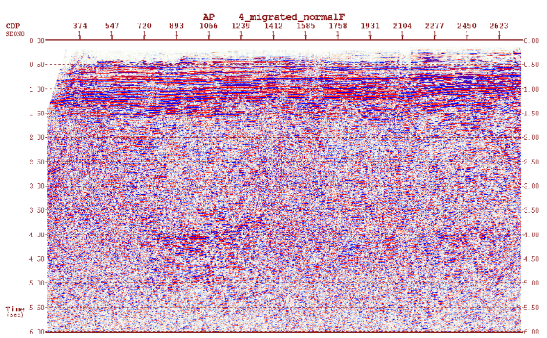

Figure-5: Migrated DMOstack with input data having frequency range 5-10-70-80 Hz

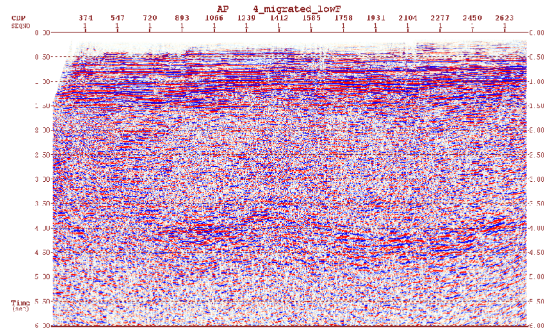

Figure-6: Migrated DMOstack with input data having frequency range 3-6-50-60 Hz

Table-1: Basic processing sequence

Geometry definition
↓
Field statics application
↓
Band pass filter
↓
Geometrical spreading correction
↓
Integration and Scalar for hydrophone data
↓
De-noise
↓
Surface consistent deconvolution
↓
Band pass filter
↓
Trace balancing
↓
CMP sorting
↓
Velocity analysis
↓
Residual statics estimation and application
↓
Imaging
(DMOstack+FXmig /PSTM+stack /TauPstack+FXmig)
↓
Random noise attenuation
↓
Time variant filter

Imaging Issues

In order to improve the imaging of deeper horizons with poor reflectivity, it is important to capture the reflected energy and to utilize it by proper imaging technique. Presence of limestone and basalt causes the absorption of seismic energy. Severe scattering at basalt-sediment boundary further complicates the problem. Moreover sharp ray bending at the base of basalt towards normal results in smaller reflection cone for sub-trappean levels, posing difficulty for velocity discrimination. This requires data with longer offset for proper velocity confidence.

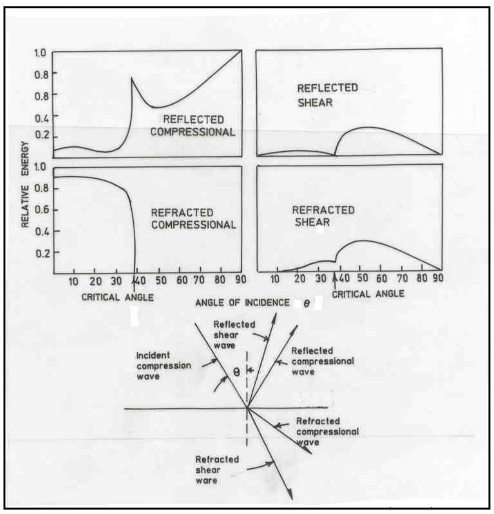

Figure-7: Partition of seismic energy for incident P-wave

Since reflection coefficient of compressional wave rises when incident angle approaches critical angle (figure-7), it is expected that at very long offsets, signal strength of reflection will be better in comparison to normal offsets.

The data was acquired with longer offsets. It can be seen from conditioned gather shown in figure-4 that near offset traces do not have appreciable coherent energy corresponding to deeper reflectors. However on traces beyond 4000 m offset, a good alignment of events is observed. Although these events are patchy in nature, if fully utilized, they may provide a reasonable image of deeper events.

Pre-stack time migrated output generated for the profile using lower frequency band of input data is given in figure-8. The results obtained by PSTM stack and migrated DMOstack are comparable in nature. This indicates that the real issue lies in the utilization of all the offsets while stacking, which otherwise are getting muted due to stretching.

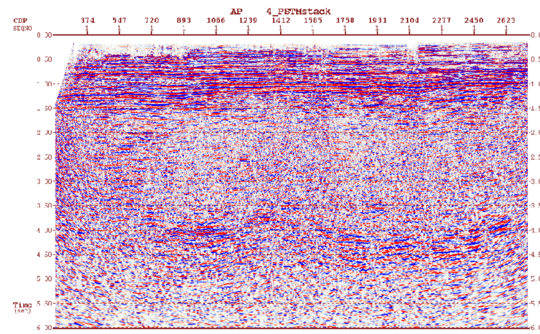

Figure-8: PSTMstack with input data having frequency range 3-6-50-60 Hz

As reported by Yadava, et al[2], Tau-P domain stacking is more capable of utilizing longer offsets in comparison to T-X domain stacking, a different approach consisting of Tau-P stack followed by FX migration was attempted on the data. Processing sequence with this approach is given in table-2. Migrated Tau-P stack of the profile is given in figure-9, which has better continuity and clarity of events in the time zone 3.5 second to 5 second.

Table-2: Sequence adopted for TauP processing

Input
(Residual statics applied CMP gather)
↓
Tau-P domain transform
↓
Tau-P move-out correction
↓
Stack
↓
F-X migration
↓
Random noise attenuation
↓
Time variant filter

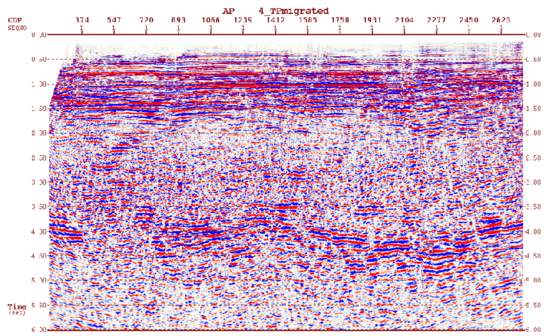

Figure-9: Migrated TauP stack with input data having frequency range 3-6-50-60 Hz

Conclusion

Long offset data pertaining to Amalapuram block of KG basin was processed adopting different processing approaches. Although post stack processing parameters were kept same, different outputs vary in quality of image. Migrated Tau-P stack has given a better image of deeper events in comparison to migrated DMO stack or Pre-stack time migrated stack.

References

1) Lithostratigraphy of Indian Petroliferous Basins, an internal report of ONGC.

2) Yadava C B, Kumar L, Niyogi K, 2006, Sub-basalt imaging using Wide-angle reflection data in Tau-P domain - a case study, presented at SPG-2006

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