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# Exploration for Hydrocarbon Below Trap in Krishna-Godavari Basin – A Seismic Imaging Issue.

***P. L. N. Sarma, R. L. Basak*, and A. K. Naithani,***
*ONGC Ltd., India, lbasak@yahoo.com*

## Summary

*The Krishna Godavari Basin is one of the country's most promising petroliferous basins, with viable & commercial accumulations of hydrocarbons on land and offshore. This basin is located along the east coast of India bordering the state of Andhra Pradesh and covers an area of 100,000 sq. km both on-land and offshore. The basin evolved through crustal rifting and subsequent drifting during the Mesozoic and Cenozoic. The basin comprises a vast range of depositional settings such as coastal plains, deltas, shelf-slope aprons and deep-sea fans. Estimated resources in the basin are around 2000 million tons of oil or oil-equivalent gas. The reservoirs are in sediments of all ages from Permian to Pliocene.*

*The seismic prospecting, being one of the most important inputs for oil exploration and exploitation, requires best of efforts and high quality outputs, so that the prospects generated yield the desired results. This study is an attempt towards optimization of Seismic acquisition and processing parameters for better & significant improvement of the quality of the seismic processed data for meaningful & enhanced interpretability of the sub-surface complexities.*

## Introduction

For the last few decades, the seismic reflection technique is most widely used in hydrocarbon exploration. Presently, the hydrocarbon exploration has reached a stage where it relies heavily on high degree of accuracy and high resolution images of subsurface generated from acquired seismic data. The advent of high frequency digital engineering seismographs designed for high resolution seismic surveys, high speed processing computers and powerful seismic softwares spurred significant improvements in the arena of petroleum seismology.

In this paper an attempt has been made to emphasize the role of detailed analysis of seismic data acquisition parameters as well as follow up processing intricacies to bring out the high resolution sub-basalt seismo-structural information in Krishna-Godavari basin. We know seismic data acquisition parameters play a key role in high resolution seismic imaging. However due to geological complexities and logistics the data acquired may not be amenable for deciphering the sub-surface. Consequently, over the decades, even if much advancement has taken place in seismic data processing to obtain accurate imaging of sub-surface structural details, sub-basalt imaging in Krishna-Godavari basin has become a numero uno problem embarked upon due to very poor signal to noise ratio as well as the presence of multiples below trap.

## Geological background of the study area

The environs under study, the eastern continental margin of India, represent a fully evolved passive continental margin and the Krishna-Godavari Basin forms a part of its southern, N-S segment (called, the Coromondal margin). The Coromondal margin, to the south of the K-G Basin is characterized by several NE-SW oriented marginal basins (including Pennar and Palar) which are arranged in an en-echelon manner (Figure-1).

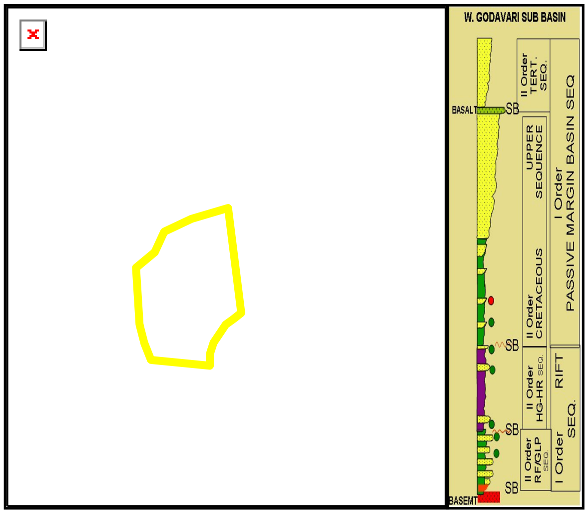



Figure-1: Tectonic Setup and identified sequence boundaries of the West Godavari Sub-Basin.

The tectonic grain in the Krishna-Godavari Basin is approximately NE-SW, which is the orthogonal to the older NW-SE trend indicated by the Permo-Triassic Pranhita-Godavari graben. A thick pile of Cretaceous and Tertiary sediments, however, obscures the seismic expression of the Pranhita-Godavari graben further to the east. Available data suggests that the Lower Gondwana Permo-Triassic sedimentation belongs to an older tectonic cycle and is attributable to an earlier phase of rifting referred to as 'Early Rift' which is superposed by a Late Jurassic-Early Creaceous rifting event referred as 'Main Rift Phase'. The identity of a separate tectonic event during the main rift phase is amply demonstrated by rotation of fault-blocks and differential erosion in different parts prior to deposition of Raghavapurum/Krishna Formation.

The post-rift subsidence of the continental margin has been divided into the early and the late drift phases. The 'Early Drift Phase' during the Cretaceous is punctuated with an igneous activity in the area proximal to the oceanic crust. Towards end of the Cretaceous, accumulation of the subaqueous lava flows south-east of the Poduru-Yanam high, may indicate the onset of the 'Late Drift Phase' of the passive margin sequence. Thinner effusives of nearly same age are recorded in the landward part of the basin as well. Slippages and slides leading to growth-fault systems characterize the 'Late Drift Phase'. The sedimentary tectonics in the coastal and offshore areas off the Krishna and Godavari rivers show systems of growth-faults and associated shale diapers.

## Comparison of Seismic data of different vintages

Detailed analyses on the seismic data of different vintages were carried out to find the root cause of the problem in sub basalt seismic imaging. Firstly, from the data acquisition point of view the field parameters of different earlier investigations were analyzed. Secondly, the processing intricacies were emphasized in detail.

The index map of the West Godavari Sub-basin along with a regional dip line D-D and a corresponding strike line S-S are shown in Figure-2. The geological sections and the seismo-geological sections of both the seismic dip & strike lines were correlated (Figure-3 to 6).

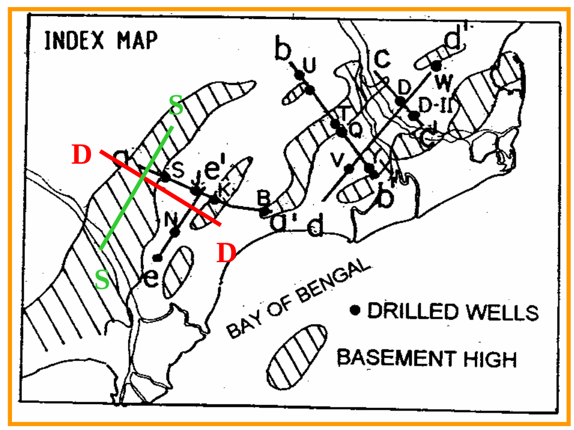



Figure-2: Index Map of the West Godavari Sub-Basin showing a regional dip line D-D and a strike line S-S.

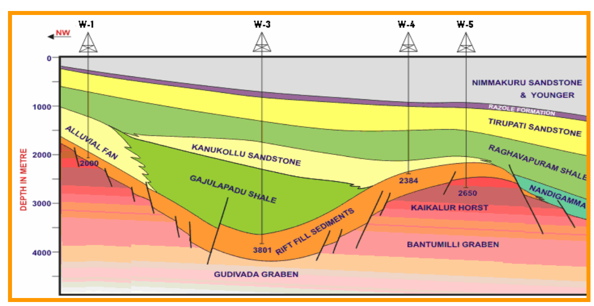



Figure-3: Geological Section across the West Godavari Sub-Basin (Dip direction).

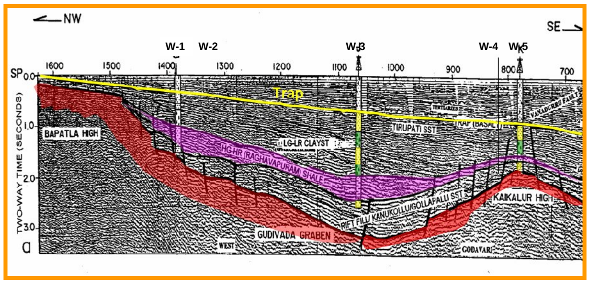



Figure-4: Seismo-Geological Section of D-D line across the West Godavari Sub-Basin (Dip direction).

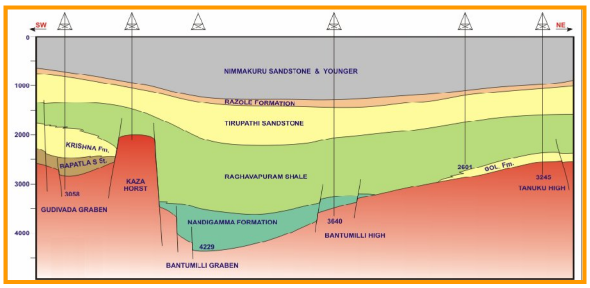



Figure-5: Geological Section across the West Godavari Sub-Basin (Strike direction).

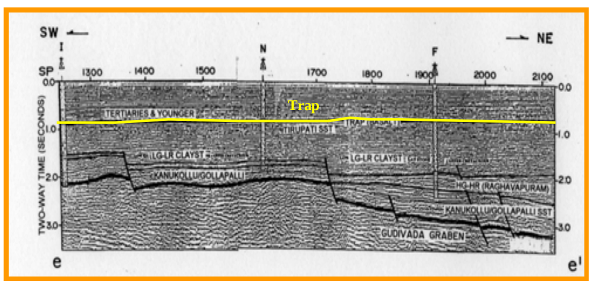
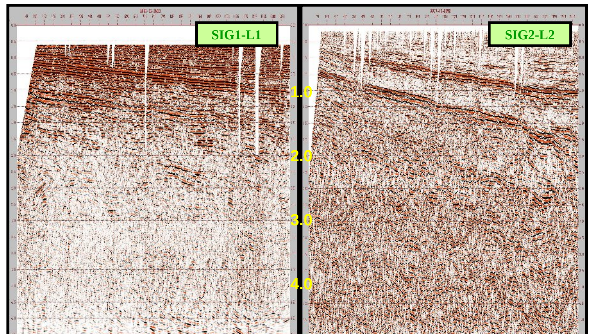



Figure-6: Seismo-Geological Section of S-S line across the West Godavari Sub-Basin (Strike direction).

By comparing the Seismic section with the perceived geological model, it is clearly observed that to obtain the high resolution sub-basalt seismic imaging is really a great problem encountered in the Krishna-Godavari Basin. But why the problem was encountered? Is it due to improper data acquisition parameters? Or, due to processing pitfalls?

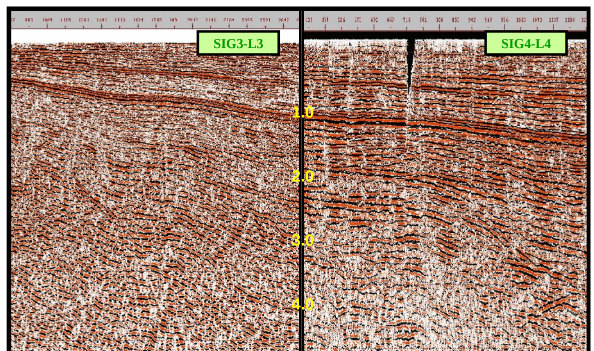
To identity the cause of problem in the real sense, the field acquisition parameters along with the seismic sections in pairs in nearly same locations but for the different investigations were compared and analyzed consequently.




| SI No. | FTO (m) | Chan./Fold | Charge size (Kg) | Depth (m) | GI (m) | SI (m) |
|---|---|---|---|---|---|---|
| SIG1-L1 | 3535 | 96 / 48 | 2.5-5.0 | 35 | 35 | 35 |
| SIG2-L2 | 3570 | 96 / 48 | 5.0 | 35 | 35 | 35 |

Figure-7: Comparison of seismic sections of SIG1-L1 and SIG2-L2 along with their field acquisition parameters.

From the comparison of the seismic sections in Figure-7, it is observed that the charge/depth was maintained more consistently in SIG2-L2 and higher charge improved the resolution of the seismic data.




| SI No. | FTO (m) | Chan./Fold | Charge size (Kg) | Depth (m) | GI (m) | SI (m) |
|---|---|---|---|---|---|---|
| SIG3-L3 | 4500 | 256 / 64 | 2.5 | >40 | 20 | 40 |
| SIG4-L4 | 3030 | 96 / 48 | 2.5 | 36 | 30 | 30 |

Figure-8: Comparison of seismic sections of SIG3-L3 and SIG4-L4 along with their field acquisition parameters.

Simultaneously, it is evident from the comparison in Figure-8 that longer offset degraded the quality of seismic section of in SIG3-L3 in comparison to SIG4-L4 and mere increase of the fold and offset did not help to increase the quality of the seismic outputs.

In the seismic data processing arena, presence of multiples, very poor signal to noise ratio and impediments to velocity determination below trap causes serious distress to image meticulously the subsurface intricacies in Krishna-Godavari basin. The processed sections along with the processing sequences for different investigations were also reviewed in detail in the study area.

It becomes a vexatious problem to the seismic data processors to delineate the high resolution sub-surface images below trap in Krishna Godavari Basin due to presence of Trap multiples, Peg Leg multiples, Ringing and very poor S/N ratio below trap (Figure-9). The multiple attenuation appears to be very cumbersome because the primaries are having very low trend velocities just below basalt and it becomes very difficult to isolate multiples from the primaries.

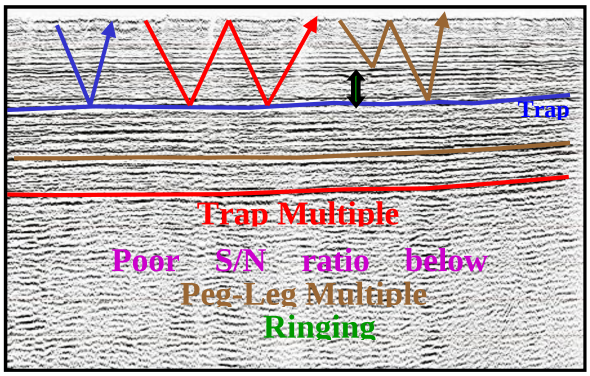
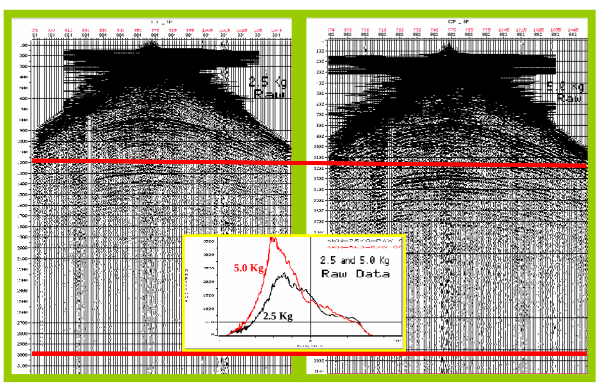



Figure-9: Problems showing trap multiple, peg leg multiple, ringing & poor S/N ratio due to presence of trap.




**(2.5 Kg)** **(5.0 Kg)**

Figure-10: Raw data showing high frequency spectrum in case of higher charge size.

Energy penetration below trap is a nightmare to the geoscientists and imaging below trap is a very crucial task in Krishna Godavari basin. Increasing charge size looks to be better in enhancement for better seismic resolution and high energy penetrations especially below trap (Figure-10).

Moreover, velocity picking in particular is a very cumbersome process in the zone of interest just below the trap. Velocities for the primary trends and the multiple trends almost follow the same gradients and virtually indistinguishable in nature (Figure-11).

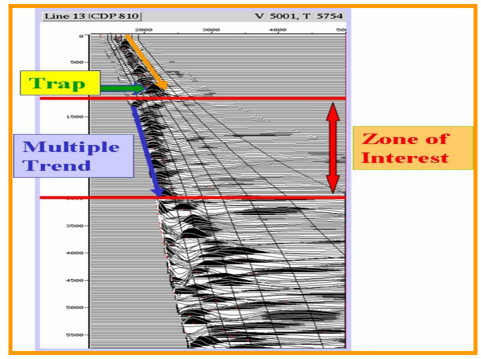



Figure-11: Problems in velocity picking as the primaries show the same lower velocity trend with multiples.

Significantly, accurate velocity analysis plays the key role to bring out the primary events more precisely and predominantly which depends on the quality of the semblances & proper velocity trends. Velocity analysis on two different locations on the same line showing the velocity picking from the good semblances brought out the better definition of the subsurface images (Figure-12). Additionally, it is evident from Figure-13, Seismic sections on two different locations on the same line using two velocity trends showing the significant differences in the processed outputs.

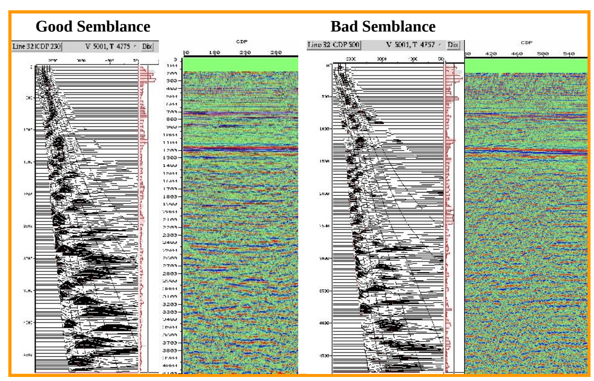



Figure-12: Velocity analysis on two different locations on the same line.

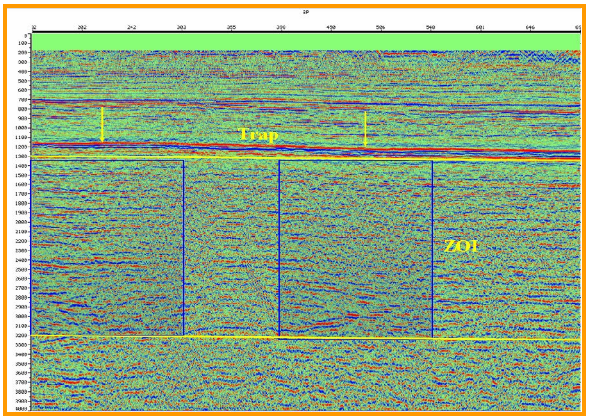



Figure-13: seismic section on two different locations on the same line using two velocity trends.

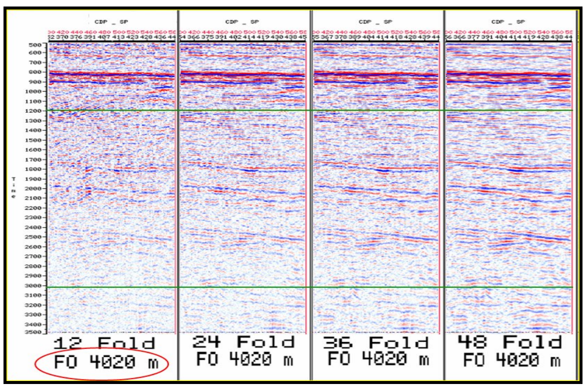



Figure-14: seismic sections pertaining to different fold for same far offset.

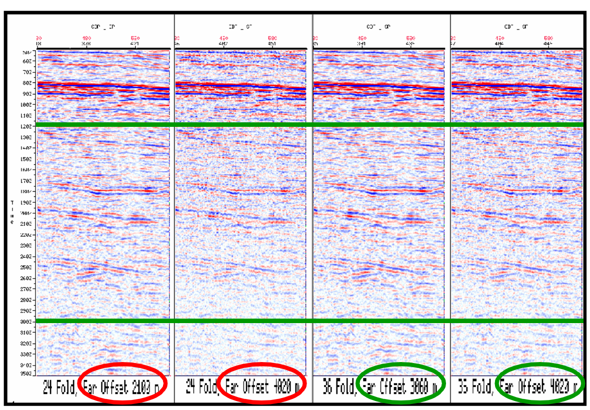


Figure-15: The improvement in increasing fold is nullified by increasing offsets.

Data fold and offsets also contribute principally in the enhancement of the subsurface complexity more precisely. Seismic sections pertaining to different fold keeping the same far offsets are shown in Figure-14. Though increasing fold appears to be good here, but the larger folds with larger offsets not essentially yield always good results (Figure-15). An optimum combination of proper fold and offsets are to be adjudicated to enhance the resolution of the sub-basalt imaging.

Predominant multiples below the trap are ruthlessly masking the primary events and hindering the true sub surface imaging sequences. In the processing domain, it is a very ridiculous task to isolate the multiples from the primaries by all latest state-of-art technologies. A representative field record in the study area replicating the predominant multiples is shown in Figure-16. A comparison of stacks with multiple velocity (wrong trend) and with primary velocity (proper trend) is shown in Figure-17 illustrating the significant improvement in the suitable sub basalt imaging.

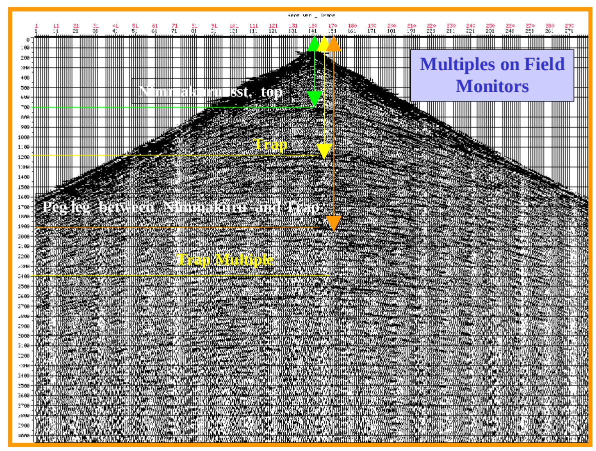



Figure-16: Field records showing different multiples.

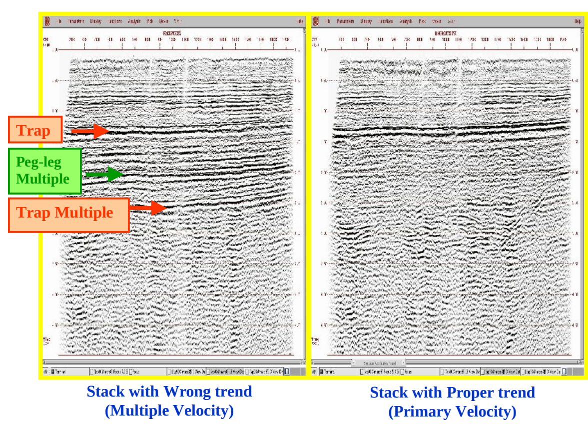



Figure-17: Comparison of Stacks with multiple velocity (left) and primary velocity (right).

## Conclusions

On the basis of the detailed analyses by comparing the seismic data of different campaigns for optimizing the seismic acquisition and processing parameters to improve the resolution of the sub basalt imaging, the findings are:

- Seismic data with short to medium offsets (2800m – 3500m) seems to be good for better imaging.
- Higher charge size and proper depth required to be more consistent to improve the resolution of the seismic data.
- Large fold with large offsets are not necessarily yielding good results.
- Proper velocity analysis de-masking primary events from the multiples below basalt looks to be hectic and ambiguous.
- Cultural noise, which is random in nature, has to be tackled at acquisition stage itself.

## Recommendations

- Where 3D data acquisition is not viable and feasible, we should not hesitate to switch over to close-grid 2D.
- As sub-basalt imaging has become a long standing problem, a special and holistic emphasis is desired towards the data acquisition, processing and interpretation.
- In view of the hydrocarbon potential of the basin, intrapreneur group concept also can be given a thought.

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