



P-122

## Dynamic modeling while acquiring seismic data

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### Summary

*It is necessary to carryout forward modeling studies to understand the seismic response of subsurface geology for meaningful seismic data acquisition. However, prior knowledge of reflector geometry, interval velocity, density etc. are essential prerequisites for a model. The seismic response is dependent on acoustic impedance contrasts across reflectors and their seismic velocities.*

*In the oil industry modeling software are available which can take kinematics and dynamics of the seismic waves. Pre-survey modeling studies help in finalization of the field parameters required for the seismic data acquisition. However, due to lack of adequate knowledge of sub-subsurface and assumptions made while carrying out the modeling studies, ambiguities and vagaries in the subsurface geology. may not give desired results. This necessitates dynamic modeling studies while acquiring seismic data, to improve upon the seismic image.*

*A case study on dynamic modeling done during 3D seismic acquisition in Mayavaram area of Cauvery basin is presented in the paper.*

### Introduction

Mayavaram area which falls in Tranquebar sub basin of Cauvery basin (Fig-1) is bounded by Madanam High in the west, Karaikal High in the east. NorthWest of the area is Kuthalam field which produces hydrocarbons in commercial quantities. The sub basin contains sediments of Cretaceous to quaternary age. It is inferred that sediment thickness in the deepest part of the sub basin could be as high as 8000m within the study area from Gravity-Magnetic and 2D seismic data. Four wells have been drilled in and around the study area and only one well encountered hydrocarbons in Archean Basement and Andimadam formation of Albian age.



Fig.1 Map showing study area

The earlier 2D seismic surveys were mainly designed to probe shallow targets and could not image the deeper sections. Since exploration of shallow prospects has reached saturation, new geological thinking is towards exploring structural and strati-structural prospects in deeper syn-rift sediments. In this backdrop a 3D survey was planned to address the exploration need.



## Dynamic modeling while acquiring seismic data



### Forward modeling & Survey Design

A four layer model (Fig.2) was generated with four interfaces viz. Cretaceous Top, Bhuvanagiri Top, Andimadam Top, Basement. Since 3D data is not available in the study area the interfaces were created from 2D lines by interpolation technique.

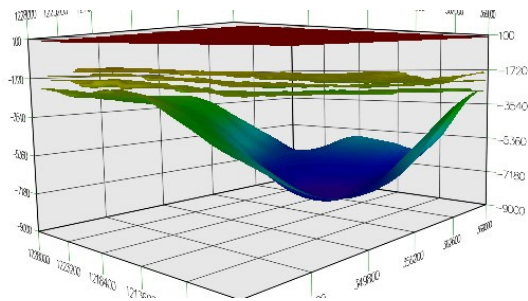


Fig.2 Sub surface model

As a part of 3D survey design, two geometries G1 (End-On) & G2 (asymmetric split spread) were selected. Geometry parameters are given in Table-1

Table-1

Parameters	G1	G2	Parameters	G1	G2
Spread	End-on	Assy. split	Spread	End-on	Assy. split
Active #s per line	288	240+48	GI	20	20
No. of receiver lines	8	8	SI	80	80
Total no. of #s	2304	2304	BS	10X40	10X40
Shots per salvo	20	20	Fold	6X4	6X4
Mini. max offset (m)	5836	4893	RLI	400	40
Maxim. min offset (m)	5006	4083	SLI	480	800
Maxim. max offset (m)	6157	5271	AR	0.48	0.48
Minimum offset (m)	41	41	X line roll	1600	1600
Shooting direction	NW-SE	NW-SE			

For selecting the geometry, ray trace modeling was carried out using MESA software. Ray tracing was done

with the two geometries by selecting the swath (swath-4) passing through the deepest part of the area. Analysis of three attributes (CRP fold, CMP-CRP displacement, CMP-CRP azimuth) for both geometries was done. The attribute plots are shown in Figures 3 to 5. Analysis has been done for basement as basement imaging is one of our main considerations.

### (G2) Asymmetric split spread

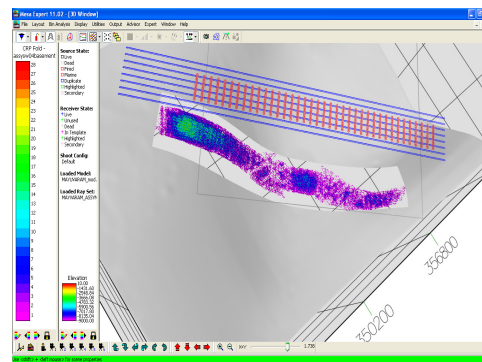


Fig.3 CRP Fold Map

### (G1) End-on

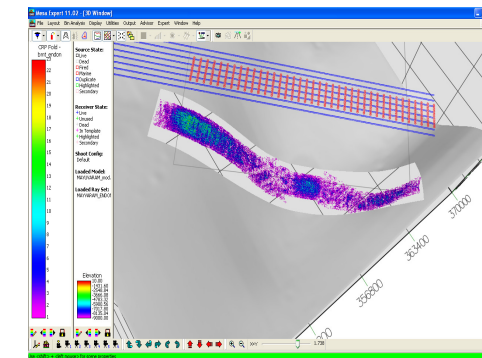


Fig.3 CRP Fold Map



# Dynamic modeling while acquiring seismic data



**(G2) Asymmetric split spread**

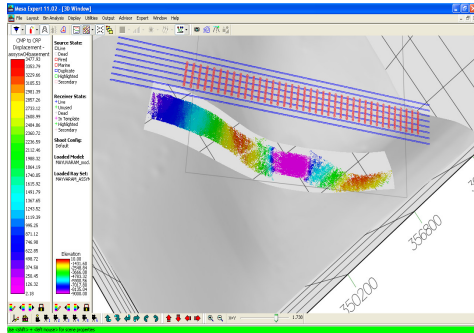


Fig.4 CMP-CRP Displacement

**(G1) End-on**

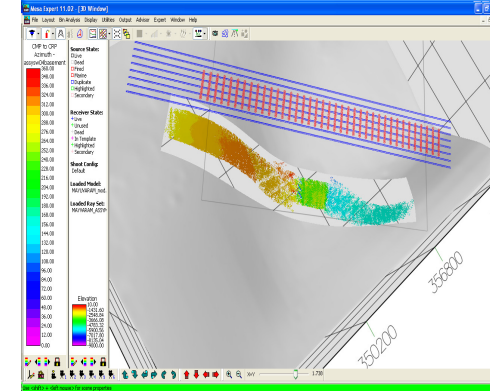


Fig.5 CMP-CRP Azimuth

**(G1) End-on**

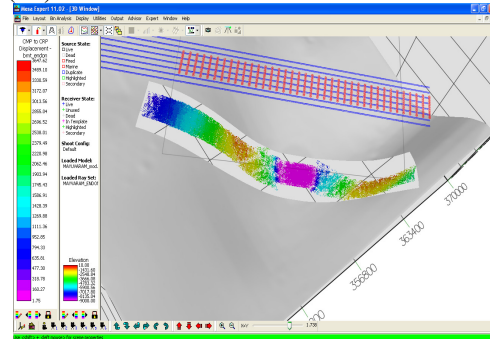


Fig.4 CMP-CRP Displacement

**(G2) Asymmetric split spread**

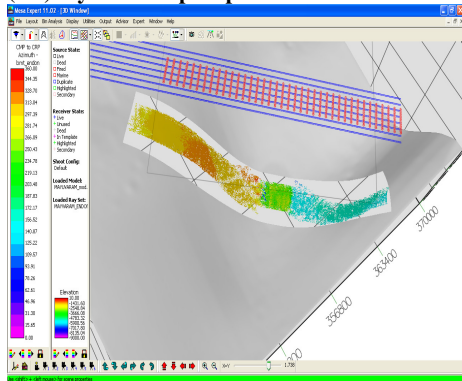


Fig.5 CMP-CRP Azimuth

CRP fold attribute display for basement shows higher fold at the centre and extreme left of the image area for end-on geometry (G1) as compared to asymmetric split spread (G2). As we move from centre to right higher fold is seen over larger area in the case of end-on geometry. The other two attributes do not show any appreciable difference between two geometries. Based on the analysis, it was concluded that end-on geometry(G1) is a better choice and was chosen for implementation as maximum offset obtainable is more than for asymmetric split spread(G2).

## Data Acquisition

Data acquisition was done on Swath-4 with G1 (End-on) geometry parameters given in Table-1. in the updip direction . After the data acquisition, processing was done upto Pre and post stack time migration. The sections inline is shown in Figure 6 and 7.

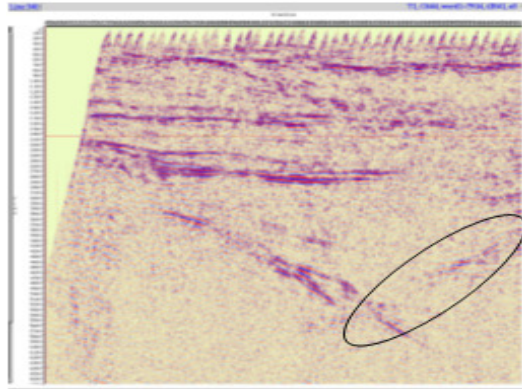


Fig.6 Stack

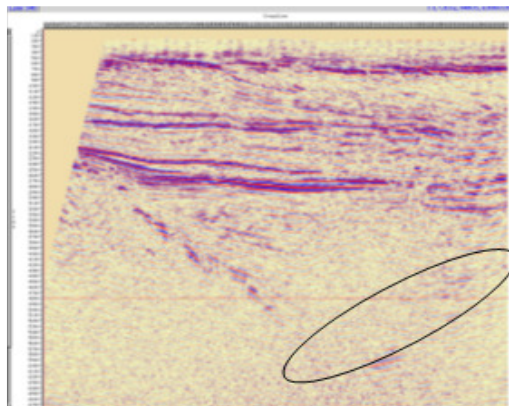


Fig.7 PSTM Stack

(Fig 6 & 7 show that the left limb of basement is clear while right limb is not clearly imaged. In the pre stack migrated section the improvement is seen at shallow level. The objective of imaging both the basement limbs including reflections abutting the limbs, were not met, which necessitated to look into the survey geometry once again.

### Dynamic Modeling using NORSAR

Since the imaging is not on expected lines a change in pattern of shooting was considered, combination of end-on shooting and reverse end-on shooting i.e. the directions of shooting was reversed to maintain the updip direction for both the basement limbs. End-on shooting from left to centre and reverse end-on from centre to right.(Fig.8). Care was taken to maintain nominal fold while changing the pattern from end-on to reverse end-on by giving adequate overlap.

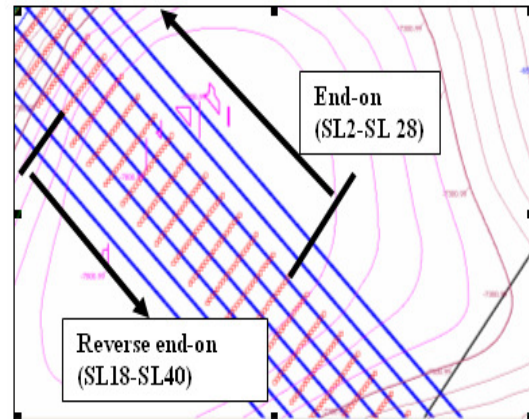


Fig.8 Modified shooting pattern

To see the effectiveness of modified shooting pattern, modeling on the same geologic model (Fig.2) was done with NORSAR software. Input files for the interfaces were loaded and grid cells of 100mX100m were made. Although bin size is 10mX40m larger grid cells were used to avoid semi-random variation between cells and at the same time including important features of the interfaces. Another reason is speed of the ray tracer is dependent on the number of grid nodes in the model. The smaller the grid increment the more the run time for the ray tracer. After ray tracing, illumination maps (Hit map, CMP-CRP displacement, amplitude density) for basement were generated for both shooting patterns and the results are discussed below

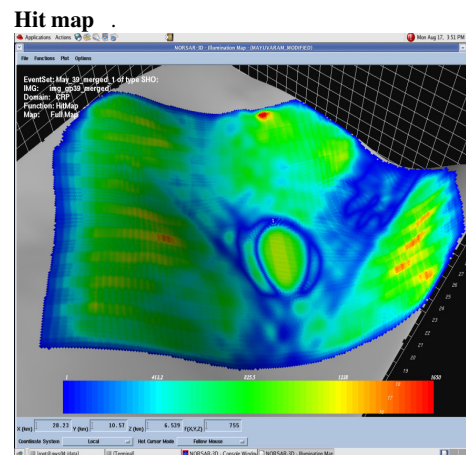


Fig.9 End-on



# Dynamic modeling while acquiring seismic data

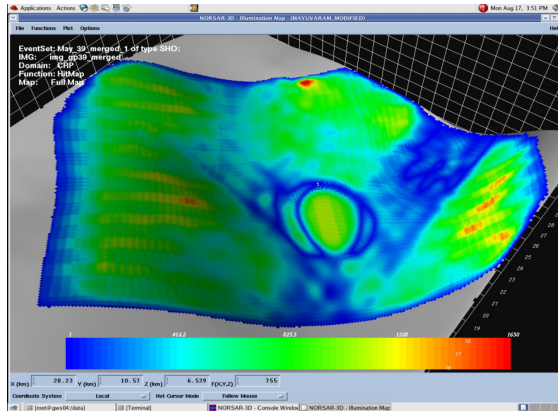


Fig.10 End-on + Reverse end-on

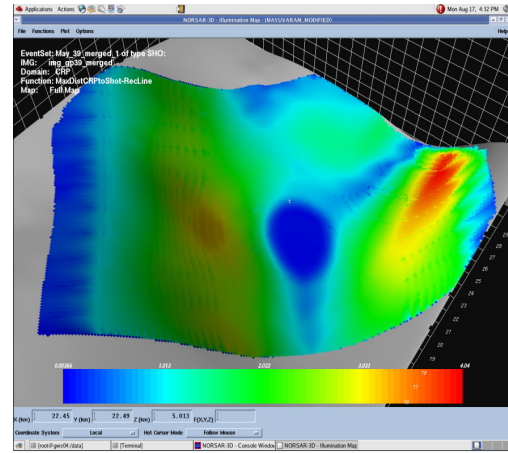


Fig.12 End-on + Reverse end-on

## CMP-CRP displacement

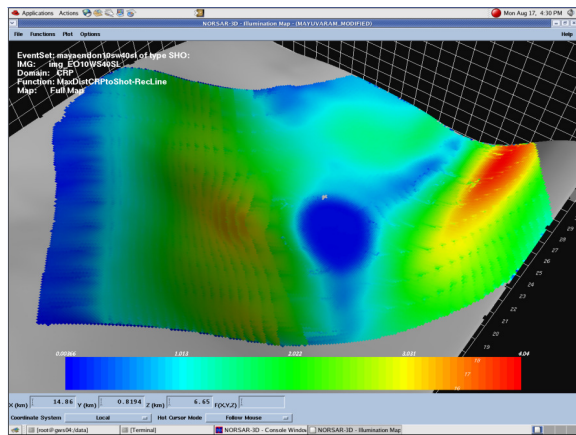


Fig.11 End-on

## Amplitude density

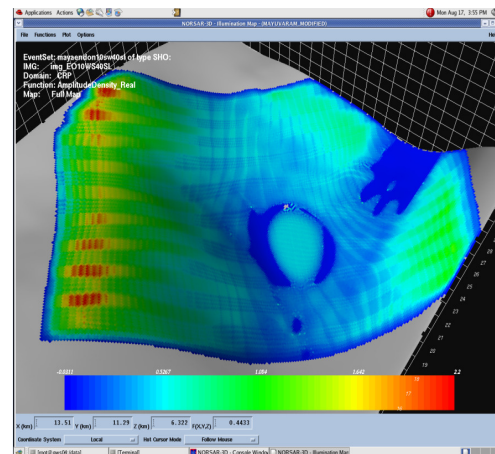


Fig.13 (End-on)

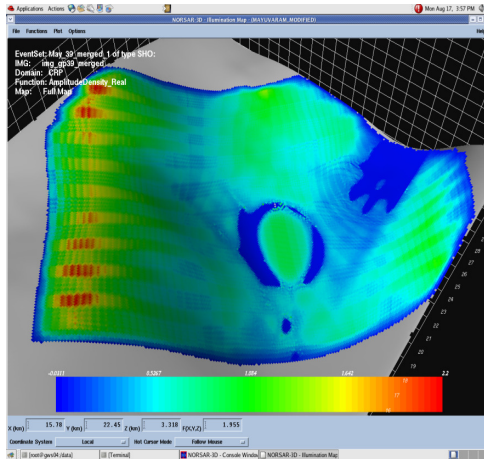


Fig.14 End-on + Reverse end-on

Hit count is higher with modified pattern of shooting  
For both geometries the CMP-CRP displacement attribute looks similar It is obvious from figure 14 that in the oval shaped area and above and below the amplitude density has higher value than in Fig.13. This means that modified shooting pattern given better results.

### Implementation of modified shooting pattern

After analysis of various attributes, Swath-2 was shot with modified shooting pattern since it has an edge over the end on geometry. The stack sections for inline 474 which is common for swath 2 and 3 are shown in fig.15 and 16. The overall strength and continuity of reflections in the rounded area in the shallow part as well as at basement level is much better for modified shooting pattern than for end-on. Both the flanks of basement are seen clearly in fig.15. Reflections which tend to abut the basement are also seen in fig.15. Migration will further enhance the reflection continuity

### Modified shooting pattern

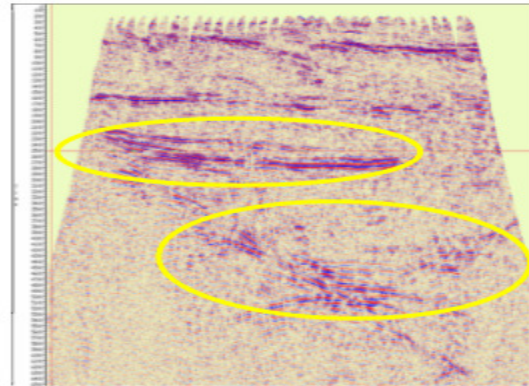


Fig.15 Stack Section IL 474 (Swath-2)

### End-on

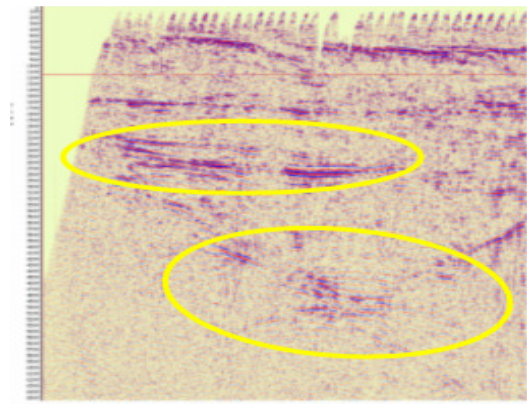


Fig.16 Stack Section IL 474 (Swath-3)

One more example of improved imaging is shown in (Fig 17. & Fig 18 ) on inline IL568 and IL572 approximately 3km north of IL 474 ( fig. 15 ).



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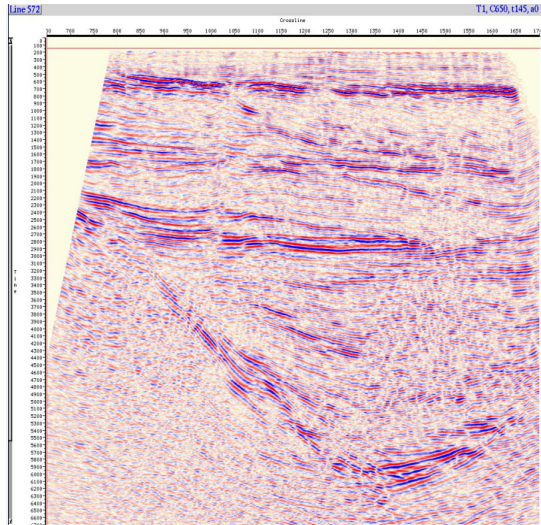


Fig.17 IL 572

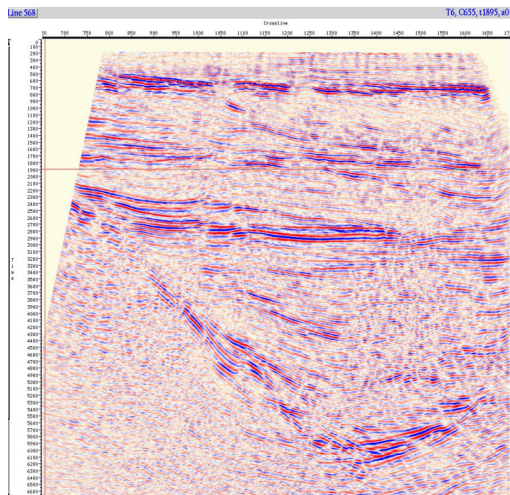


Fig.18 IL 568

### Conclusions

Since seismic survey is expected to bring out the geology for prospect generation a lot of effort has to go into acquisition methodology. Seismic modeling is an effective tool for designing parameters for better sub surface imaging. Dynamic modeling studies has helped in mid course correction in shooting pattern to get better sub surface picture.

### Acknowledgements

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