An Innovative Acquisition Design for Optimum Focusing of Multiple Objective Seismic Data

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Summary

Seismic data acquisition, especially 3-D data, plays a very important role in exploration for hydrocarbons. It is a dream come true to acquire an ideal 3-D volume because it is prohibitively costlier to acquire on a commercial scale. There are various geometries adopted for acquiring 3-D seismic data which are essentially a compromise made on certain parameters. These compromises are based on area of coverage, active channel requirement, zone of interest etc. The only compromise we do not want to make is on the quality of data to fulfill the Geological & Geophysical objectives. This paper suggests an innovative acquisition design to acquire 3-D seismic data, for focusing various zones of interest, in a cost effective way. A case study is also presented, implementing the geometry design. The effectiveness of the acquisition design, to satisfy the objectives, is brought out in the sections shown as example. This type of judicious mix of mini & maxi lines can be used in suitable combinations to focus the objective zones and acquire quality 3-D seismic data in cost-optimized manner

Introduction

Seismic data forms the basic foundation over which is built an ambitious structure for the hydrocarbon exploration. It has always been the dream of every explorationist to have at hand a set of ideal seismic data that is well focused towards his geological & geophysical objectives (G & G objectives). An ideal 3-D data volume, which is essentially the sampling of a 5-D wave field W (t, X_s, Y_s, X_r, Y_r) can effectively provide the solution & reduce the risks involved in exploration (Vermeer, G.J.O, 3-D seismic survey design, SEG, 2002, p17). But acquiring such data on a commercial basis is so prohibitively expensive, that, any practical geometry for acquisition has to be a compromise on many parameters involved, based on the exploration objectives. The objectives are generally scattered in different time zones, which can be broadly classified as shallow, intermediate and deep. The objective can be single or multiple, in various combinations of the above time zones. The general approach for an effective acquisition design, for multiple objectives, is to broadly group the objectives in the form of a time window and design an acquisition geometry for the particular time window. In such cases the focus no longer remains 'sharp' but gets de-focused according to the combination of the time zones involved. This scenario does not help the explorationist in the stratigraphic analysis of 'pays & plays' and 'subtle traps'. Moreover the design may involve more number of channels, than needed, to generate the traces with desired offset ranges & foldage, within the time zones of interest. This may not prove to be very cost effective.

In order to overcome this 'focusing problem' of, say, a shallow as well as deeper objective, an innovative and cost-effective acquisition geometry is suggested in this paper. This geometry involves a judicious mix of 'mini' and 'maxi' receiver lines, with varying number of active channels, in a symmetric orthogonal acquisition set up. The basic aim of this 'mix' is to provide adequate traces with the near to intermediate range of offsets for the shallow objective & longer offsets for the deeper objective. The efficacy of this geometry can be explained with the help of a test design as discussed below:

Seismo–geological parameters for the test design

Let's consider the seismo-geological parameters, as given in the following table for the design of acquisition geometry .

Area & Extent (Sq. Km)	100
Depth of Interest (m)	500 – 2600
Time Zone of interest (ms)	500 – 1000 & 1500-2200
Average Velocity (m/s)	1800 - 2400
Dip (degrees)	5 – 10
Foldage desired	36 – 48
Max.offset	3000 M

The Geometry

Keeping in mind the dual objectives, the choice of geometries was narrowed down to two with the help of

MESA software. The geometries have similar parameters for comparison. The main considerations for the design were,

i) To ensure sufficient foldage for the shallow zone (around 10 fold)

ii) To ensure better offset distribution in the range of 0-600 M

iii) To ensure optimum coverage & offset distribution for the deeper objective, in spite of the presence of logistic challenges like aqua culture, back water & reserve forest areas in the southern part.

The features of the two geometries considered are tabulated below:

Parameter	Orthogonal	Orthogonal (mini-maxi)
Bin size	25 x 50 m	25 x 50 m
No. of RL's	6	9 (5+4)
No.of Channels per line	110	5X120 + 4 X 20
Shots/Template	24	20
Line Interval	200 m	200 m
Shot Interval	100 m	100 m
In line roll	250 m	250 m
X line roll	1200 m	1000 m
Fold	66 (11 X 6)	68 (12 x5+ 2 X 4)
Xfar	3233 m	3310 m

Attributes of the geometry

The geometries & their attributes are given in the Fig.1 -8 . The Orthogonal geometry with mini & maxi lines has 9 receiver lines 100 M apart, with 5 lines consisting of 120 channels (Maxi lines) at 200 M interval & 4 lines consisting of 20 channels (Mini lines) each at 200 M interval (Figure- 1). The other geometry has 6 receiver lines with 110 channels each in an orthogonal set up (Figure-.2). The attributes of the geometries like, azimuth Vs. offset (Rose diagram – Figure- 3 & 4), trace distribution Vs. offset (Figure 5 & 6) and sample offset distribution in a few bins (Figure 7 & 8) are given for both the geometries.

From the comparison of the statistical offset-fold distribution of traces (Figures 5 & 6), it is apparent that the Orthogonal with mini-maxi combination is superior because of :

a) More no. of traces in the 0-600 M offset range , focusing the shallow objective.

b) Comparable no. of traces for the middle & far offset ranges for focusing the deeper objective

c) Optimum no. of shots required for covering the area

d) Sufficient foldage cushion for possible loss of foldage due to logistics

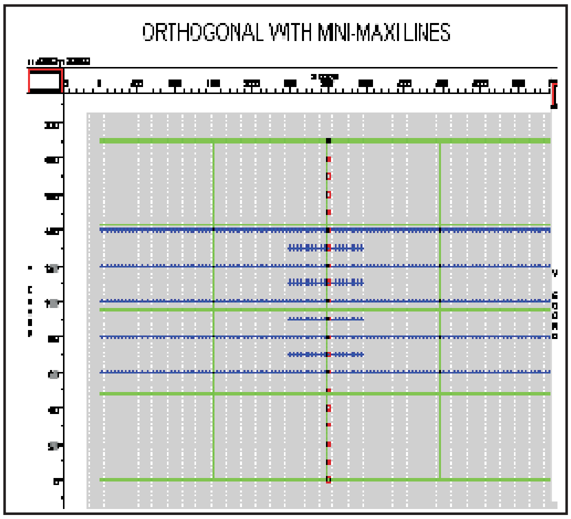

Fig.1. Receiver template with 5 lines (120 channels each) & 4 lines (20 channels each) – mini-maxi combination.

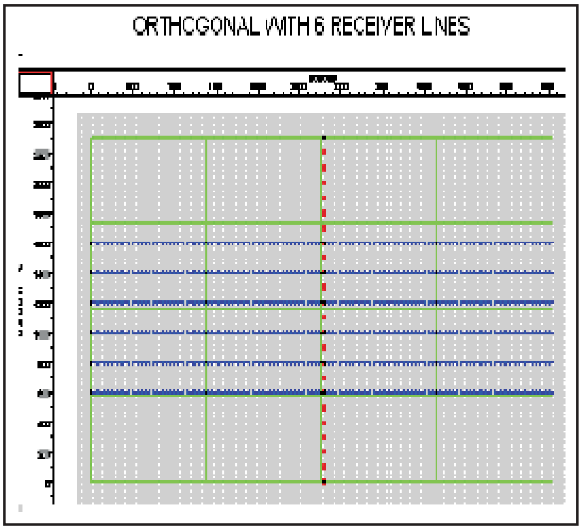

Fig.2 : Orthogonal receiver template with 6 receiver lines (110 channels each) setup

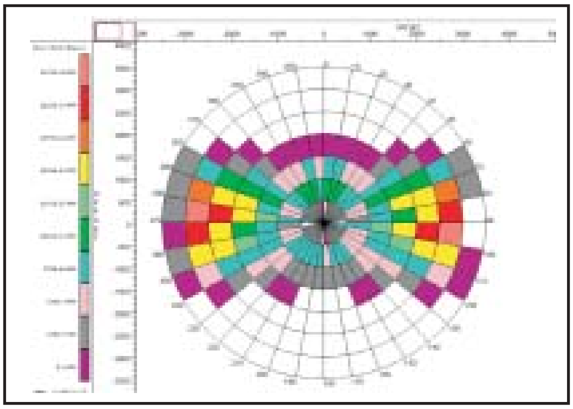

Fig.3: Rose diagram – Azimuth distribution in Mini-maxi combination, 9 receiver lines .

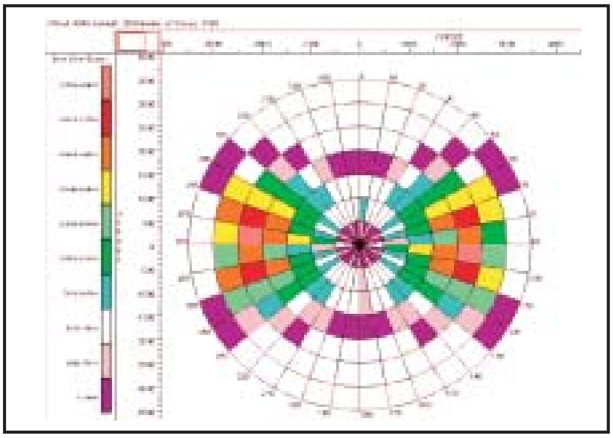

Fig.4 : Rose diagram – Azimuth distribution in Orthogonal 6 receiver lines

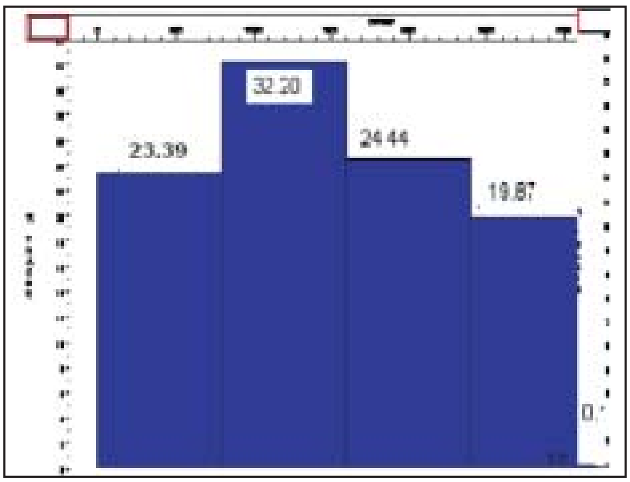

Fig.5 : Trace distribution Vs. offset – Mini-maxi combination, 9 receiver lines.

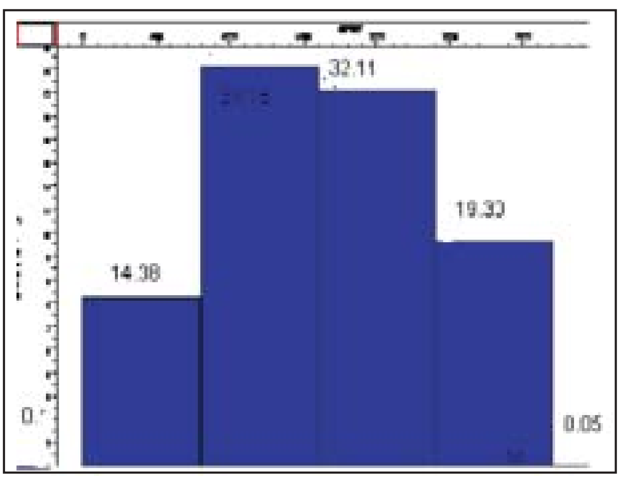

Fig. 6 : Trace distribution Vs. offset – in Orthogonal 6 receiver lines

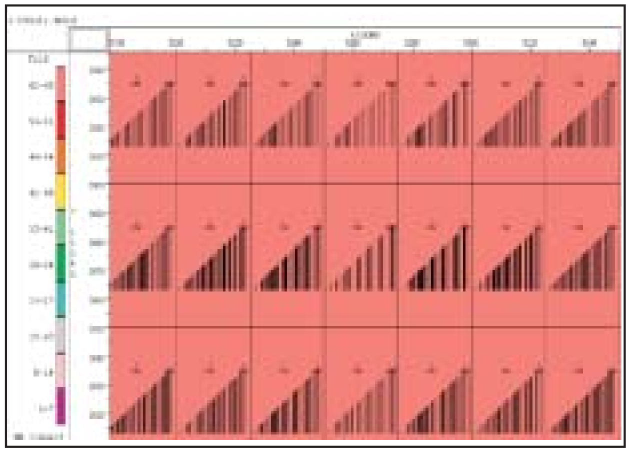

Fig. 7 : Offset distribution – Mini-maxi combination, 9 receiver lines

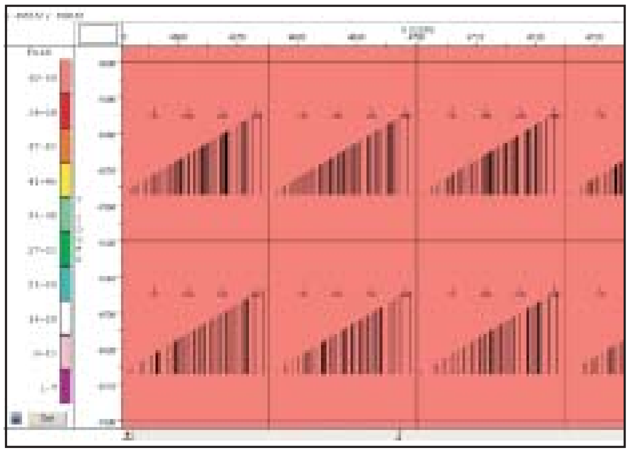

Fig. 8 : Offset distribution – Orthogonal 6 receiver lines

Overall this geometry has contributed towards even distribution of offsets, proper focusing of the dual objectives, optimization of in-puts & cost.

Case study

The above geometry was implemented successfully for 3-D data acquisition in the Krishna-Godhavari basin in Eastern Indian on-shore. The index map in Figure 9 shows the area of acquisition. The generalized stratigraphy of the area is given in Figure 11. The zones of interest for the acquisition were, a shallow zone in the range 500-1000 ms & another in 1500-2200 ms.

The data has shown encouraging results as evidenced in the seismic section in Figure 10, which was processed during acquisition in FPU, up to brute stack. This figure shows the improvement in the shallow zone (500-1000ms) by contribution from mini lines. The figure 12 shows the

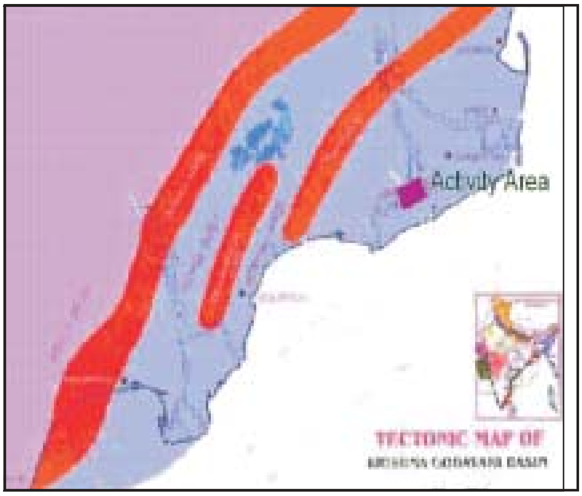

Fig.9 : Location map of the 3-D acquisition discussed under case study (marked as activity area)

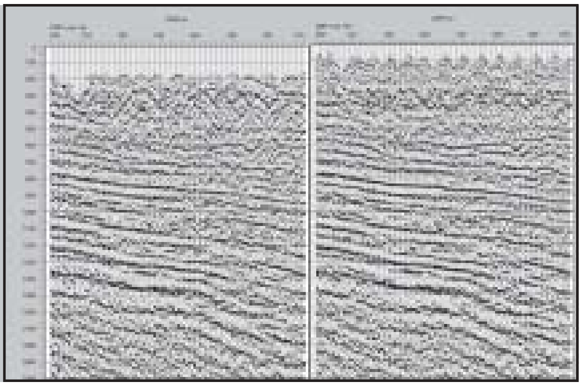

Fig.10 : Comparison of contributions from maxi lines (left side – 60 fold) & mini-maxi combined (right side – 68 fold)

merged volume of two acquisition campaigns, including the above case study. In this section, left of L 340 belongs to an earlier vintage & right side belongs to the current campaign. It is seen that the mini-maxi combination, orthogonal data has improved resolution & continuity as marked in the boxes.

Figure 13 shows another section of the 3-D volume under the case study. The marked zone shows improved fault delineation which was identified as the trapping mechanism for the gas struck in that area. The improvement brought about in the shallow zone as well as the deeper zone is striking . The resolution & clarity brought in by this particular campaign has opened new leads for further exploration in the area.

Conclusions

The above case study establishes that this type of judicious mix of mini & maxi lines can be used in suitable combinations to focus the objective zones. This design results in cost reduction because of optimization of active channels, at the same time maintaining the required quality for fulfilling the G & G objectives.

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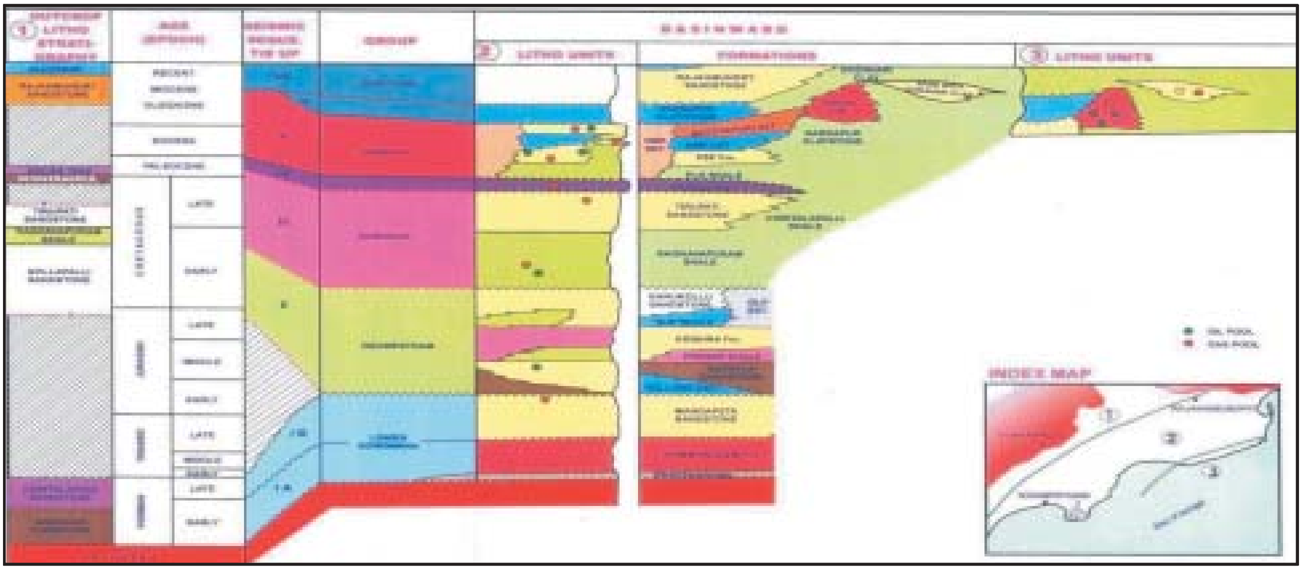

Fig. 11 : Generalized stratigraphy of the operational area of the case study

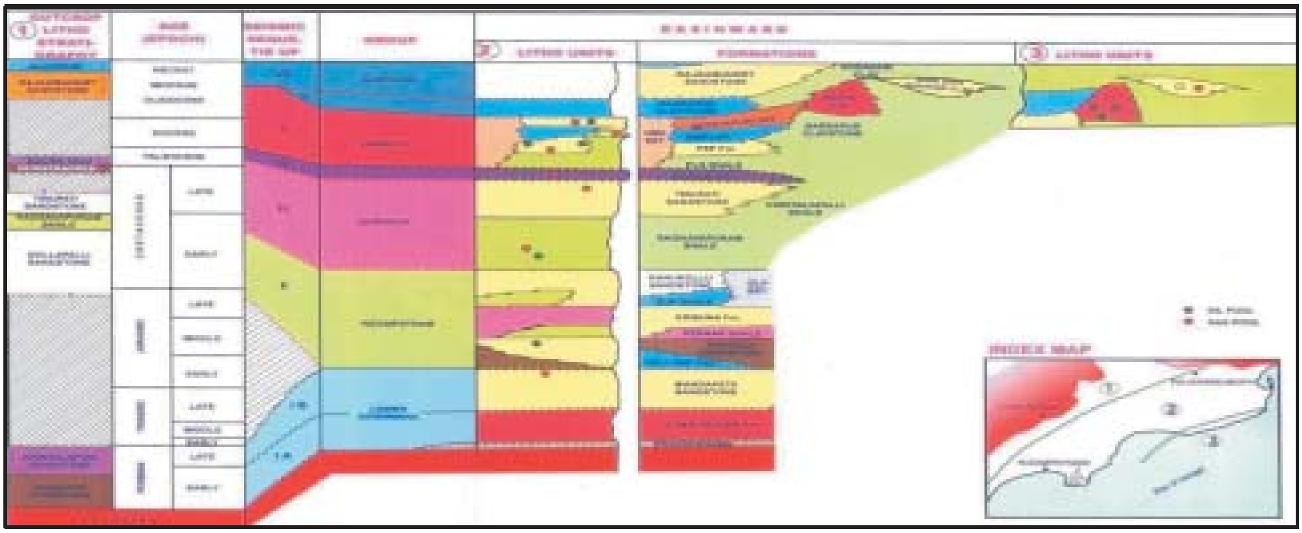

Fig.12 : Merged seismic section of 3-D volume of earlier campaign & present study – Line at L340 separates the two campaigns. The boxed portions show the improvement in data quality.

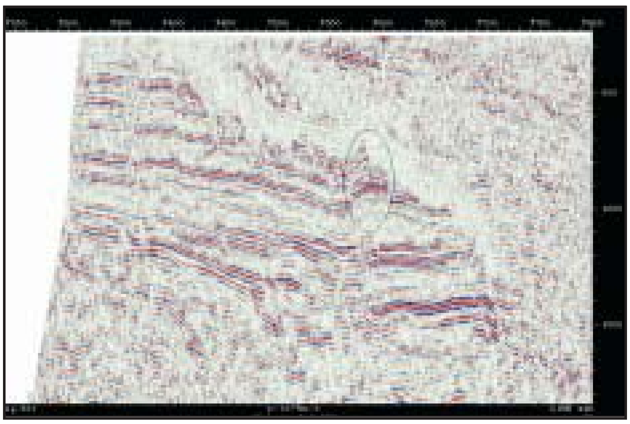

Fig.13 : A typical processed section of the 3-D volume under case study. The marked area shows clarity in fault delineation , which was helpful in locating gas reservoirs in this area. This provided further lead for exploration..

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