8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-110

3D Pre Stack Merging – A Case History in Cauvery Basin

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Summary

3D Seismic survey has taken it's birth somewhere in mid 80's in India. During the last two decades many of our production and key exploration areas have been covered with 3D seismic surveys, which have been recorded over a period of time using a wide variety of recording equipments, different charge size and shot hole depth, variation in spread lengths, bin dimensions, grid orientations, offsets & fold etc. The goal for 3D merging is to establish a way to combine these original data sets so that one consolidated 3D volume is produced, which simulates as closely as possible, what could have been produced had all the 3D's been recorded and processed as one project. The present work intends to match & merge multi surveys (three seismic investigations) acquired by three seismic crews in the onland areas of Cauvery Basin in India during the year 2007-08 field season. These parties have been deployed during a span of six to seven months and were asked to acquire the data in the three adjacent areas with an overlap of half swath role. The data has been processed meticulously which could enable to arrive a near perfect match of the sub surface geological model. A comparison has also been given with the earlier processed 2D & 3D data in this area with the present 3D merged volume. The present merge 3D processed section reveals images the subsurface upto basement configuration, better than earlier & brings out an improvement in the seismic section compared to the earlier processed section.

Introduction

Three seismic crews have been assigned to acquire 3D Seismic data in Tulsapattinam-Kovilkalappal area in Nagapattinam sub-basin of Cauvery Basin, during the field season 2007-08. The parties have acquired 433 Sq.Km (FFM) of 3D data under three different seismic investigation nos A ,B & C. The operational area is located geologically in the southern part of Nagapattinam sub-basin, which is bounded by Karaikal ridge in the north, Pattukkottai - Mannargudi ridge in the west, Vedaranyam horst in the east and Ramnad-Palk bay sub basin in the south. Narimanam and karaikal are the producing fields on Karaikal ridge and Kovilakalappal field is producing on the Pattukkottai – Mannargudi ridge.

Background

The area is situated to the South east of the Kovilkalappal field. It is bounded in the east and south by a NELP block operated by Niko Resources and in the North by Tiruttaraipundi high. Area covers a small oil field viz. Tulsapattinam. A part of the area under C has already been covered by earlier 3D seismic data (69SKM) and the area under A has been covered by 3D seismic data . This campaign was acquired with the prime objective of delineation of Tulsapattinam pay (post rift Nannilam formation). Additionally a few 2D seismic data from 5 campaigns is available. A total of 9 exploratory wells have been drilled in and around the area. However Tulsapattinam-1 is the lone hydrocarbon bearing well in the area. Though most of the wells drilled on the intra grabenal high (Tulsapattinam high) have been terminated within the Bhuvanagiri formation (Cretaceous, ref: Fig-1). However, the current 3D is joining both the field, Kovilkallapal & Tulsapattinam with a objective to image the basement configuration more precisely than earlier having state of the art technology instrument , more channels & offset as the input.

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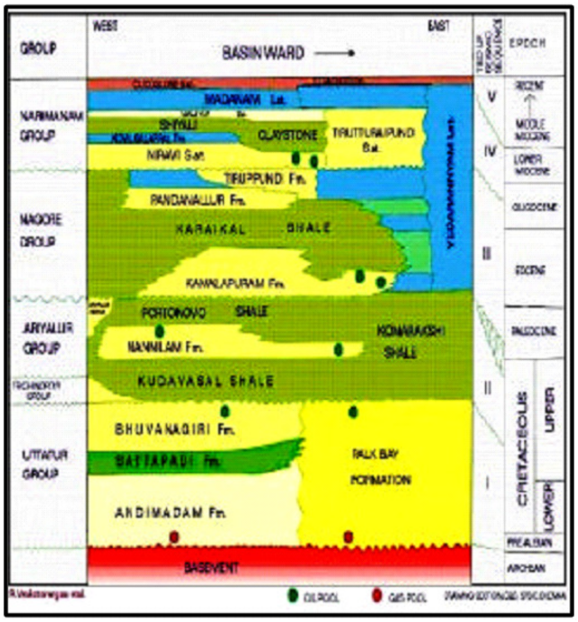

Fig-1: Generalised stratigraphy of Cauvery Basin

The location map of the area is depicted in Fig-2.

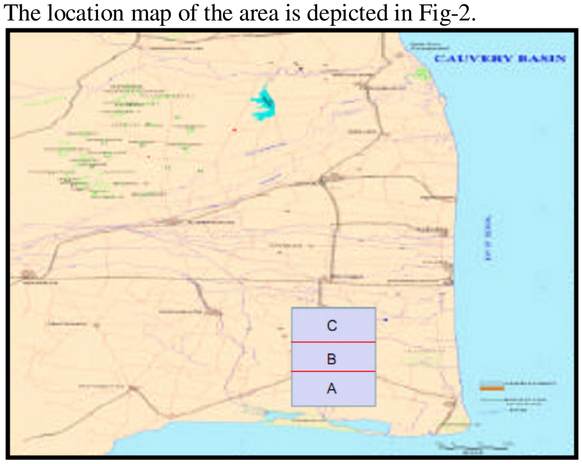

Fig-2: Location Map of the area

Geology of the Area:

The operational area falls in the Nagapattinam depression. Within this depression Tiruttaraipundi, Tirupundi highs and vedaranyam platform are present. All these are independent basement highs controlled by faults extending up to the Cretaceous top. Well A-1 situated in the Southern part of the sub-basin was drilled up to intra-basinal high Oil is being produced in commercial quantities (@ 20 tons a day)from Object-I (282-2285, 2288-2290m) from a sand within the lower part of Nannilam formation. Pay sand gross thickness is nine meters with intervening shale and net pay thickness is 6.5m.

The Well K-1, drilled to the west of A-1 found to be dry as sands of A-1 has shaled out. T-2 drilled (towards Northeast of A-1) on a basement high was also found to be dry and Bhuvanagiri formation is absent in this well. The well (A-2) drilled on Tulsapattinam structure was also found to be dry. Another well A-3 drilled based on the seismic data of campaign "A" in Fig-1 also found to be dry.

Hydrocarbon prospectivity of the area

The proposed area covers the Tulsapattinam oil find. This oil discovery was made in the year 1987 and is on production since then. A small area of 69 SKM was covered with 3D (1998-99) to chase A-1 pay. Base on this data one well (A-3) was drilled which went dry due to lack of reservoir facies. With the available scanty 2D and little 3D seismic data, a new play viz,syn-rift fills has been conceived for exploration in this area. Success of this play will open up a large area for exploration, which present 3D is proposed. This 3D survey joins the two fields viz. Tulsappattinam & Kovilkalapal. Additionally few structural (4way closure), fault closure) and strati – structural prospects in the form of wedge, up-dip pinch out etc have been mapped which needs to be detailed through proposed 3D. Lows around intra-grabenal Tulsapattinam high has sufficient generation potential to charge the envisaged plays.

Reasons for 3D survey

The proposed area is covered by earlier by 3D seismic survey in the year 1998-99 with 20 X 40 Bin size, with the prime objective of delineation of Tulsapattinam pay (shallower play). But the quality of 3D seismic data is not sufficient to resolve deeper play or map the envisaged Stratigraphic features. Additionally, the frequency content in the available data is also low, as a result various seismic attributes attempted with Tulsapttinam 3D did not produce realistic output. As a result the high potential area remained under explored all these years. Thus this part of area is proposed for repeat acquisition with 20X20 Bin size.

Methodology & Procedure

Geometry Merging

The insertion of geometry through SPS & swath wise geometry merging of the data has been carried out. A total no of 24000 shots have been checked superimposing offset on the first breaks, keeping it in a video mode (fig-3), which enables that the shot and receiver co-ordinates are correct, which in turn provides offsets. After merging the geometry with the data through SPS, the bin gathers are generated.

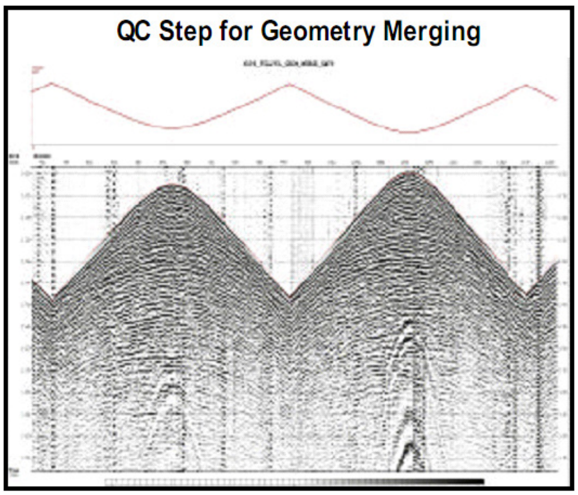

Fig-3: Offset superimposed on first breaks

Removal of Dead Traces

Before noise attenuation, it is required to eliminate the dead traces present in the dataset. Dead traces are identified as zero or near zero average amplitude traces consistently over different time windows. The pre stack merge fold for the three investigations is shown in fig-4.

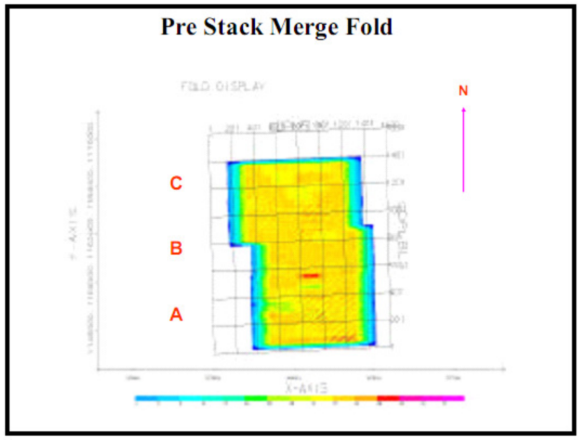

Fig-4

Noise Attenuation of Shot Gathers

The noise predominantly seen in the land data are due to logistics, cultural, power line, transmission error etc. Clean pre-stack gather with enhanced signal to noise ratio is an essential pre-requisite for appropriate velocity estimation for migration and AVO studies. In order to achieve this, it is to be ensured that high amplitude noise and other cultural noise which are often unavoidable during land data acquisition has to be attenuated during the initial stages of processing.

The shot sequence data is taken into consideration for noise attenuation in different stages after application of spherical divergence correction. For ground roll attenuation, Low frequency array filtering is used, whereas, amplitude scaling method is used for attenuation of high amplitude / cultural noises.

The dataset in cdp gathers is analyzed across small overlapping spatial and temporal windows by comparing the window amplitude with the amplitude of corresponding window on neighbouring traces in the data. For each trace and each time gate median RMS amplitude is found from the amplitudes of corresponding gates in the neighbouring traces in the dataset. Only nonzero samples are used for computation of the amplitudes. The median is compared to the gate amplitude in the trace. If the trace gate amplitude exceeds a pre defined threshold amplitude, which is supplied by the processor, the trace gate is scaled down to specified amplitude.

This process is applied in shot-offset, receiver-offset & cdp-offset domain to get a desired result.Fig-5 shows the final conditioned decon gather with respect to the initial raw gather along with spectrum analysis.

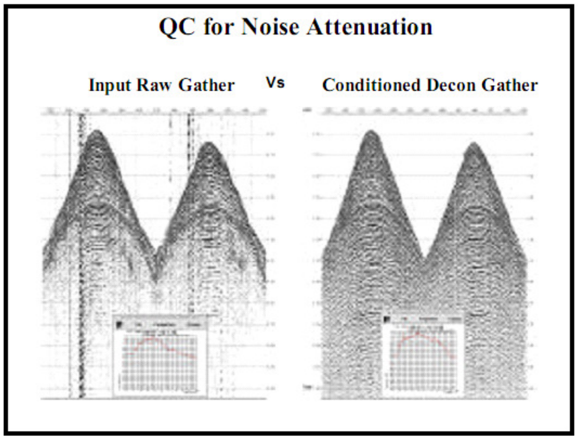

Fig-5: Raw gather vis-à-vis noise attenuated gather

Field Data Example

Fig-5 shows the result of application of this process on representative raw shot gathers.

The generalized basic processing flow & PSTM is mentioned in Table 2.

The area of investigations (A,B & C) carried out by different instruments and charge & depth size also varies from one investigation to the other. The area A is covered with asymmetrical split spread & the other two area were covered by symmetrical split spread. A schematic diagram has been shown in fig- 6 below.

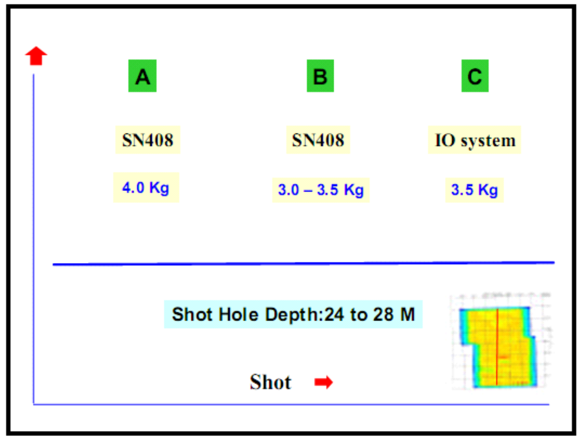

Fig- 6

For this purpose proper amplitude balancing & a matching filter has been designed so that the three parts looks to be a seamless section.

The processing sequences is mentioned in Table-1.

Table 1 : Processing Sequences

1	Raw Data	11	Decon stack	21	Pick RMS velocity from TM gathers, reversing NMO
2	Format Conversion	12	First pass velocity analysis (400 M X 400 M)	22	Prepare RMS velocity volume
3	Geometry Merging through SPS	13	First pass residual static correction	23	Smoothened RMS velocity volume along grid
4	Manual Editing of transmission errors	14	Second pass velocity analysis (400 M X 400 M)	24	Migration aperture Test
5	Spherical Divergent correction	15	Second pass residual static correction	25	Anti alias filter test
6	Application of field statics	16	Residual stack	26	Run PSTM
7	Noise suppression	17	Conditioning of gather	27	Mute & Stack
8	Surface consistent amplitude balancing & matching filter	18	Conversion of stacking velocity to RMS velocity by DIX formula	28	Residual move out analysis & application
9	Surface consistent deconvolution	19	Preparation of RMS velocity volume	29	Application of RNA & TVF
10	Band Pass Filter	20	Run 1st TOTM in every 5 lines	30	SEG Y conversion

Fig- 7 shows the section before & after amplitude balancing & matching filter, whereas Fig-8 shows a zoomed portion of it.

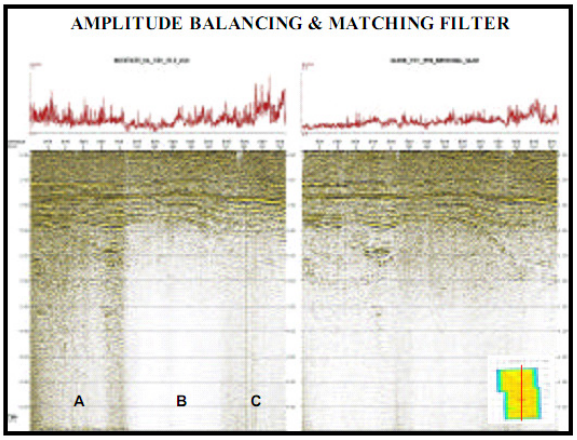

Fig- 7

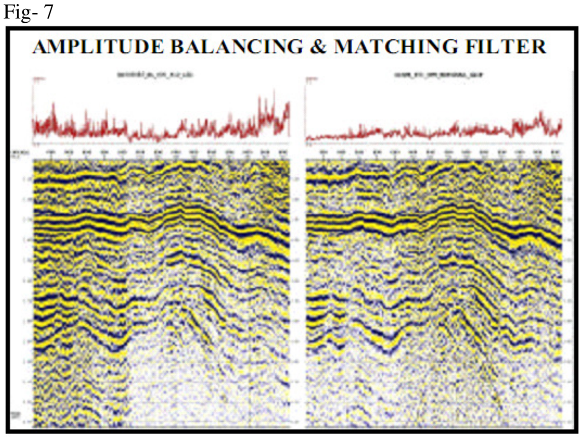

Fig- 8

Velocity Analysis & PSTM

The velocity analysis has been done (200M X 200M) very meticulously keeping in view the condition of flatness of time migrated gathers in each semblance point. Fig- 9 shows the QC check while picking RMS velocity directly from the time migrated gathers inversing NMO. Utmost care has been taken while picking the RMS velocity at the basement level. In this level in some places where there is a sharp dip specially in the flank part the basement, where the stack section seems to be poor, the RMS velocity pick has been performed by zooming the RMS velocity semblance and basement continuity has been taken into consideration in the stack section at the time of picking the velocity at that level. This procedure provides a better estimate of RMS velocity for any particular CDP point to migrate the data to provide best results in the pstm output.

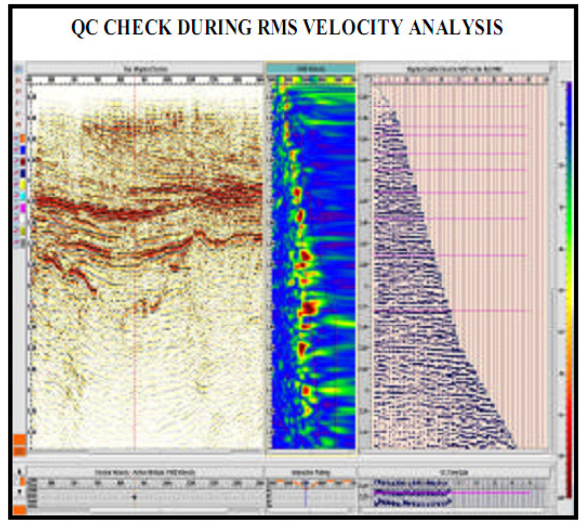

Fig- 9

Fig-10 shows the QC check while doing residual move out analysis.

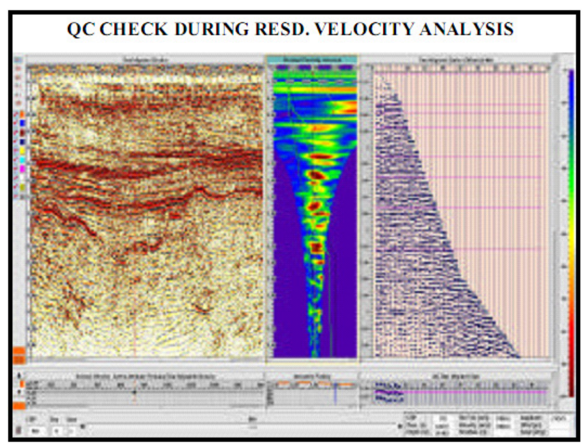

Fig- 10

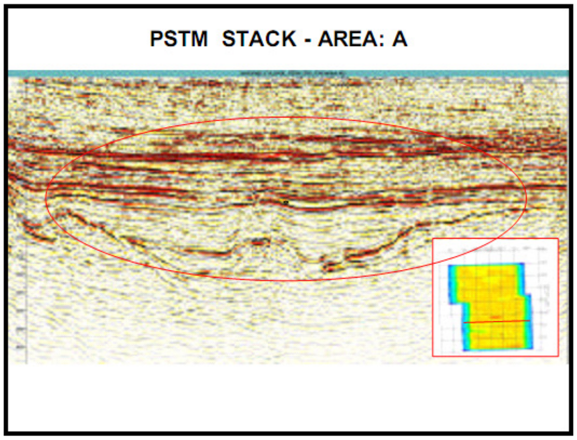

Fig- 11

Data Analysis & comparison with earlier vintages

The present processed data for the three areas(A,B & C) are shown in Fig-11,12 & 13 respectively. The inset foldmap shows the inline position in the grid.

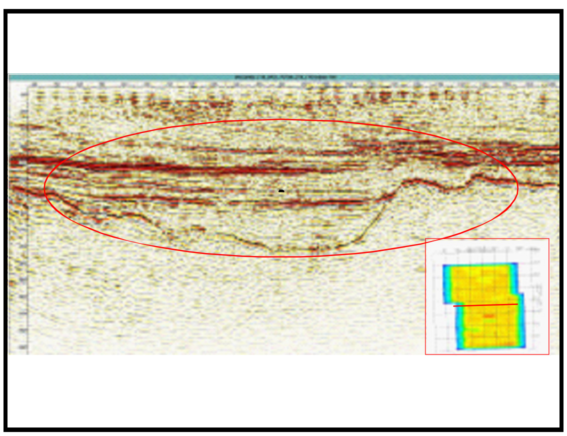

Fig- 12

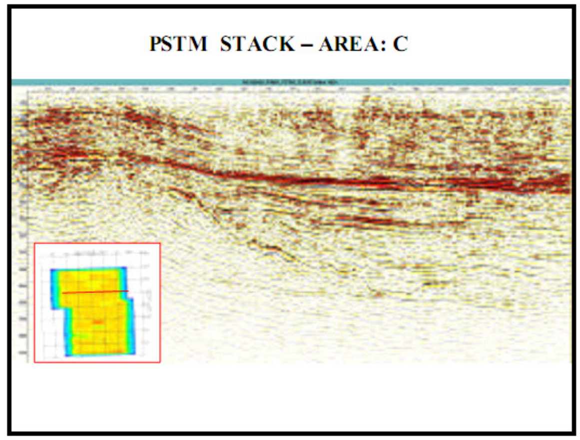

Fig- 13

Fig-14 shows the comparison between old 3D (Area-A) & new 3D , where A#1 well position is inserted. In Fig15, comparison is between old 3D(Area-A) & new 3D in the well position A#2, which was oil bearing. Theses two figures shows that there is a substantial improvement in the present section over the earlier.

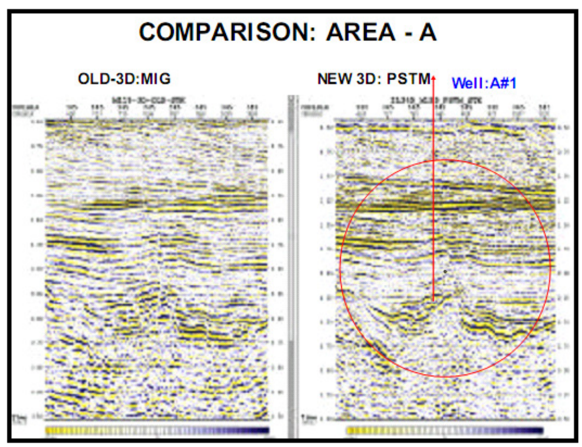

Fig- 14

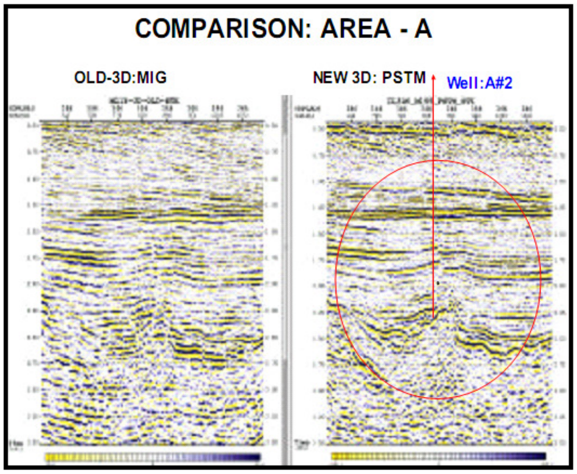

Fig- 15

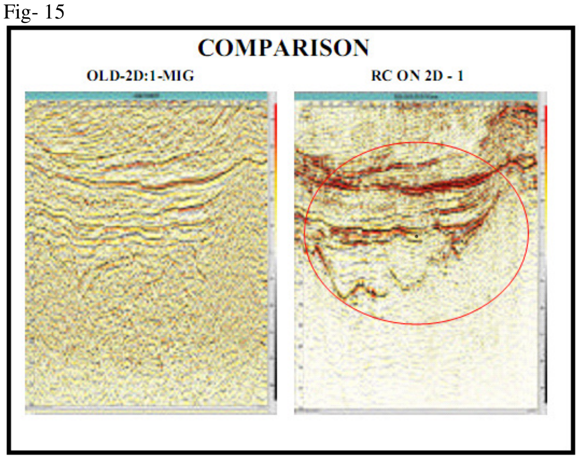

Fig- 16

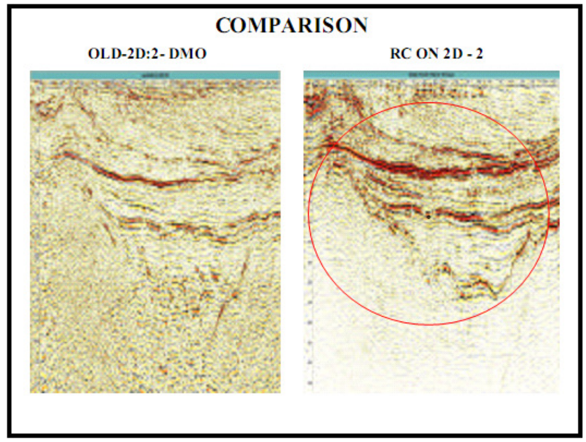

Fig- 17

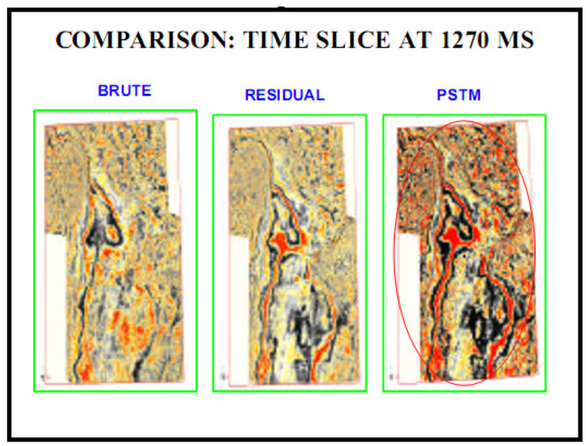

Fig- 18

Fig-16 & 17 shows the comparison between the earlier 2D vintages and the RC line on the new 3D volume. Both the cases there is a notable improvement is seen over the earlier 2D section. Fig-18 shows the comparison of the time slices in different stack levels viz. brute, residual & PSTM at time 1270 ms.

Conclusions

The earlier 2D & 3D vintages of the study area, where the seismic sequences were not resolved for proper interpretation. The new 3D seismic line along the said 2D section (Fig-17 & 18) and 3D section (Fig-15 &16) reflects the better resolution of seismic facies enabling the structural interpretation of the data more meaningfully. Thus, a typical half-graben rift basin model can easily be inferred from the new 3D seismic. In addition, the data also brings out a few, better-defined strati-structural anomalies suggestive of a drastic improvement in output data quality. Thus , the processed 3D seismic data has resulted in a noticeable improvement in output data quality enabling better interpretation.

Based on geological observation, core data and electro log data. One object in the interval of 2290-2288 m & 2285-2282 m (Bhubanagiri formation) was tested conventionally in the well A-1 , which has produced oil @ 600 lts/hour through 8 mm bean. The well A-1 was completed as oil producer. The well A-2 was drilled towards NE of A-1 & A3 to delineate the pay sand of A1 and assess the hydrocarbon potential of Bhubanagiri formation. In well A-2, the pay sand is developed in the interval of 2396-2398m & 2401-2402m ,in A-2 as well but in the form of hard streaks. Whereas in the well A-3, the A-1 pay equivalent is represented mainly by shale with a thin tight siltstone streaks, which are devoid of hydrocarbon. Bhubanagiri sands are developed in the interval of 2483-2650m and interpreted to be water bearing.

The well was dry due to the fact that A-1 pay equivalent has shaled out except for a few thin tight streaks of nonreservoir character, as in A-2. In order to chase A-1 pay, it would be better to probe further eastwards of A-3, where there is structural advantage, closer to east boundary fault which appears to be the main migration path, but subject to availability of reservoir facies.

The current 3D survey after interpretation will reveal much better about the lateral extent of the A-1 sand in all directions from the well A-1, as no such offset VSP was available for the well A-1, which may tells the lateral extent of the A-1 pay and reasons for non availability of the pay in the other wells and provide a better location for future drilling in the vicinity of the aforesaid structure, since the current 3D imaging is the best possible sub-surface image available with the interpreter as on date in that area.

Acknowledgements

The authors express their deep sense of gratitude to Oil & Natural Gas Corporation Limited to provide technical & infrastructural facilities to carry out the above work.

The authors sincerely thank Shri G.Sarvesam, GGMHGS for his continuous help and tremendous encouragement to carry out this work and permitting to publish the paper.

The authors also thank Shri Chaman Singh, GM(GP) & Shri BSN Murthy, GM(GP) for their help in connection to this paper.

Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

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