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Imaging a Sharper Strati-Structural Anomaly through Iterative Velocity Model Building and Pre Stack Time Migration - A Case Study in Indian Context

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Summary

The problem of imaging the sub-surface accurately is always a challenge to the Geoscientists. This requires a proper understanding of the geology of the area/basin, objective of survey, adequate acquisition geometry to delineate the prospect and overall a smart processing of the data. In this paper a 3D land data pertaining to Cauvery Basin has been taken into consideration for 3D PSTM. Kirchoff Pre Stack Time Migration (PSTM) is a more advanced and technically accurate processing algorithm, and due to reduction in computing time, it is being used in a large scale in the Oil industry as a basic processing tool. The by product of PSTM processing, CRP gathers through Kirchoff algorithm can regularize the acquisition geometry, through geometrical weighting. This uniformity in fold distribution in the whole dataset can help in focusing the exploration targets with confidence. Further the imaging capabilities of PSTM was shown by generating seismic attributes to prove that interpreters have more confidence in delineations of reservoir parameters. Earlier 2D section did not give any confidence to the interpreter to map the basement & strati-structural anomaly in this area. The present 3D processed section reveals the basement configuration better than earlier & brings out an improvement in the seismic section compared to the earlier processed section.

Introduction

Imaging the subsurface in a geologically complex area is always a difficult task and the cost of computation through PSTM/PSDM has made it a costly affair. Which type of migration algorithm has to be adopted for processing depends upon the complexity of geology and velocity of the area and governed by the diagram depicted in Fig-1. When the complexity of the structure is from moderate to complex & the velocity in the area is not very complex, then PSTM gives good results. The post stack migration holds fairly good for a combination of simple structure & moderate velocity complexity in the area. Kirchoff Pre Stack Time Migration (PSTM) is a more advanced and technically accurate processing algorithm which is used commonly in the industry as a basic processing tool. The by product of PSTM processing, CRP gathers through Kirchoff algorithm can regularize the acquisition geometry, through geometrical weighting which arises because of non uniform fold acquisition especially in the land data. This uniformity in fold distribution in the whole dataset can help in focusing the exploration targets with confidence. An additional advantage of Pre Stack imaging is that, it has the potential to retain amplitude variation with offset and phase change. Further, the 3D PSTM algorithm can also take care to get regularize acquisition geometry, so that the acquisition footprint on migrated volume is reduced to a greater extent.

The conditioned decon gather with applied residual static & RMS velocity volume are the only two pre-requisites for running a PSTM job. For a Pre Stack Time Migration to produce good image, it is mandatory requirement that the input time gathers are noise free and the RMS velocity volume is adequate to flatten the time migrated gather. Whereas, post stack migration is less sensitive to velocities but Pre Stack Migration requires very accurate velocities.

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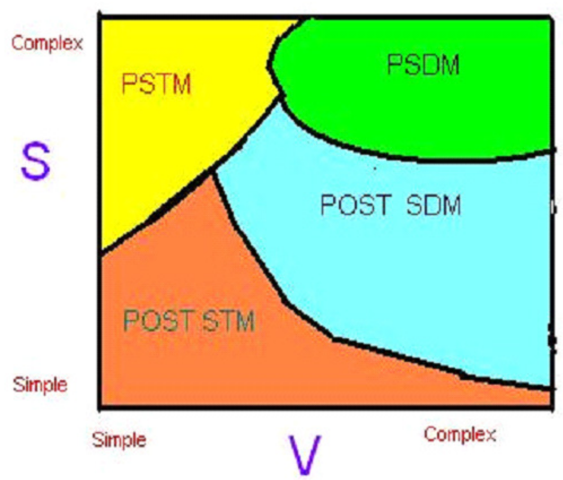

Fig-1: Processing algorithm to be chosen from above diagram

Geology of the Area:

The study area (Fig2) is located in the southern part of Tanjore sub-basin of Cauvery Basin – the southernmost peri-cratonic Mesozoic rift basin with Cretaceous and Tertiary clastic sedimentary sequences overlying the Archaean granitic Basement (Fig3). Syn-rift Lower Cretaceous Andimadam formation and fractured basement proved gas-bearing in the vicinity of study area thereby making these strati-structural propsects as main exploratory objectives of the present 3D vintage. The sub-basin is covered by about 2250GLK of 2D seismic surveys and about 350 sq.km. of 3D Seismic surveys. About 26 wells were drilled in the sub-basin of which five proved hydrocarbon-bearing. The present 3D vintage has been acquired to identify the strati-structural prospects within Andimadam and fractured basement levels.

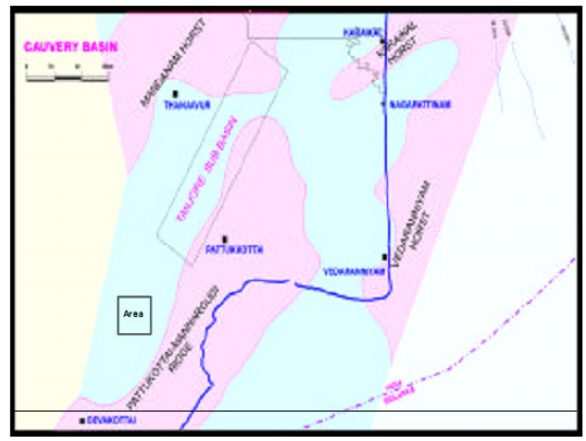

Fig-2: Location map of the area under investigation

Objective of Study:

The objective of study of this paper is to image a sharper strati-structural anomaly of the above area through iterative velocity model building through 3D pre stack time migration (PSTM).

Methodology & Procedure

Input Data

Shot gathers of 3D surveys pertaining to Cauvery Basin (location map shown in Fig:2) were chosen for this purpose. The field data is loaded in the system after internal format conversion. After merging the geometry with the data through SPS, the bin gathers are generated.

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.

Noise Attenuation

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.

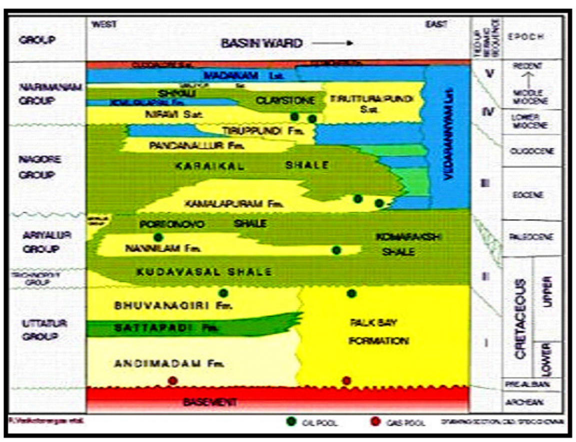

Fig-3: Generalised Stratigraphy of Cauvery Basin

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The dataset in 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 as well as in Receiver-offset domain to get a good result. Fig-4 shows the result of application of this process on representative raw shot gathers. A is the input, B is the output and A-B is the difference.

A B A-B

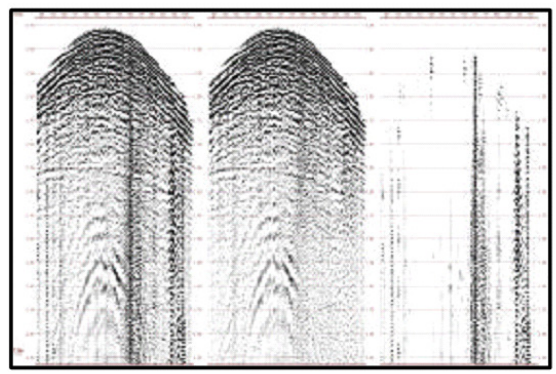

Fig-4: Raw gather vis-à-vis noise attenuated gather

Field Data Example

Fig-4A shows the stack comparison before & after noise attenuation.

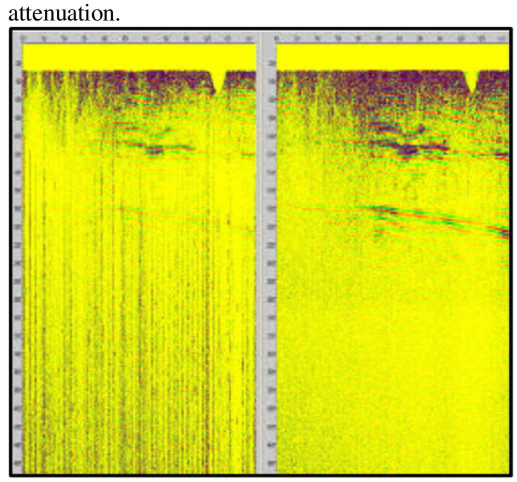

Fig-4A: Stack Comparison

The generalized basic processing flow is mentioned in Fig-5.

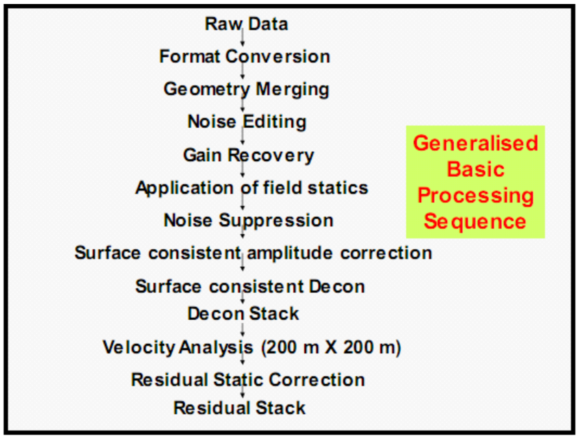

Fig-5: Generalized Processing Flow chart

A decon test has been performed from spiking to predictive having varying predictive distance(160 ms to 300 ms with a interval of 20ms) and lag (8ms to 32 ms at an interval of 4ms) .The final parameter of decon has been chosen with the consultation of the user group. In this case a decon with operator length 240 ms and pd 32 ms has been chosen .A section of decon test is shown in Fig-6 opposite.

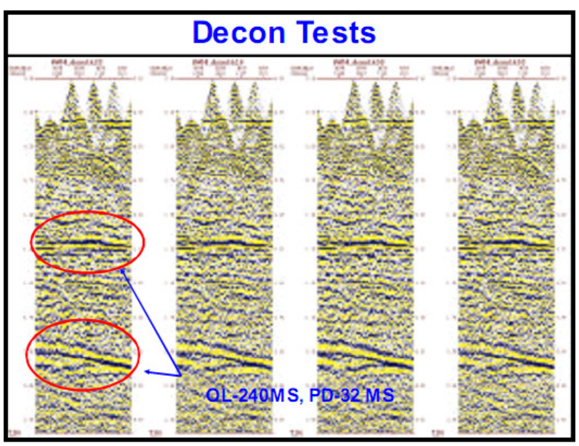

Fig-6: Deconvolution Test

Frequency spectrum before & after decon is shown in Fig-7, where Fig-8 shows the frequency spectrum before and after noise attenuation.

A clean decon gather is a pre requisite for pre stack migration. So the conditioning of the CDP gather is an important task. Fig-9 shows the conditioning of CDP gather before and after noise attenuation.

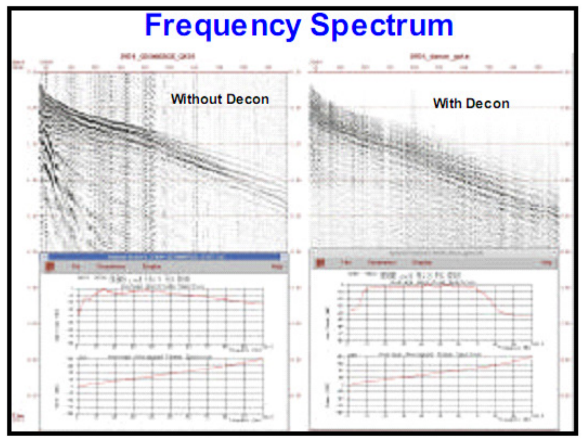

Fig-7: Frequency spectrum before & after decon

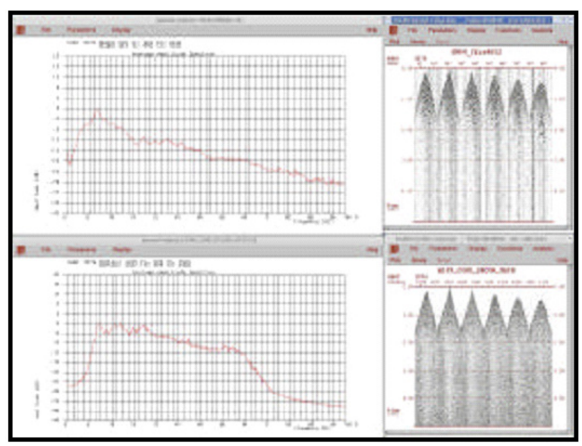

Fig-8: Frequency Spectrum before & after NA

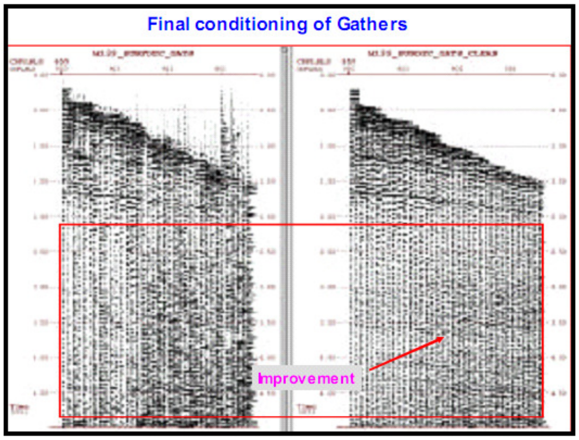

Fig-9 : Conditioning of CMP Gather

Pre Stack Time Migration

The processing sequence for 3D PSTM is depicted in Fig-10. The basic input for running the first TOTM (Target Oriented Time Migration) is a conditioned decon gather with applied residual statics and a RMS velocity volume. The stacking velocity obtained from basic processing is converted to RMS velocity by DIX conversion and used in first TOTM.

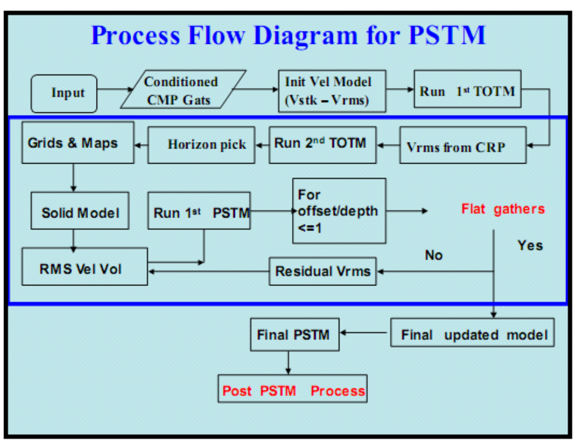

Fig-10: Processing Flow Diagram for PSTM

Due to non uniform fold acquisition, especially in the land data, fold compensation is done through geometrical weighting which allows weighing of selective offset and azimuth ranges and defines output in offset classes (Fig-11). The outliers can be stripped off through histogram.

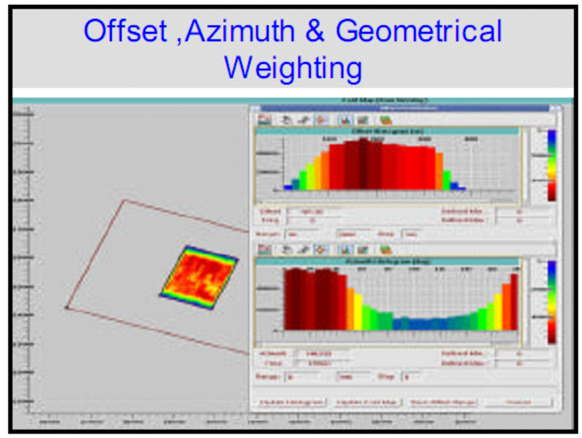

Fig-11: Geometrical Weighting

Iterative Velocity Model Building

RMS velocity analysis is then performed on the PSTM gathers (Fig-12) and run the second Target Oriented Time Migration (TOTM) with an interval of five cross lines. On the TOTM output section major horizons are picked and provided by the user group.

These picks have been converted in grids & time migrated horizon maps. Then, the velocity along the horizons have been extracted from the RMS velocity volume. These velocity maps have been then smoothened & prepare a solid velocity model. Fig-13 & 14 shows the RMS velocity maps in basement level (before & after smoothing) and T surfaces (Triangular) created from velocity maps. Fig-15 shows the 3D solid velocity model, which is the input for running final PSTM.

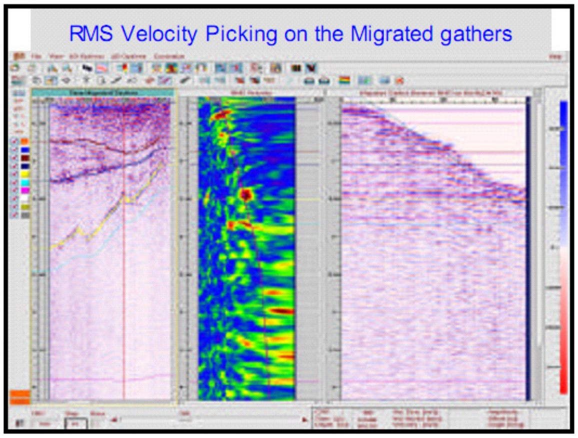

Fig-12: RMS Velocity Analysis

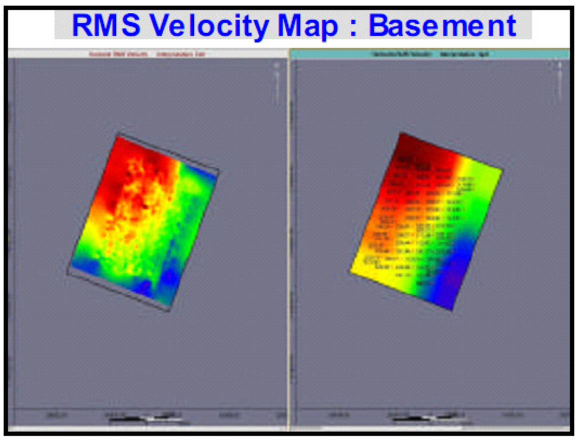

Fig-13: RMS Velocity Maps before &after smoothing

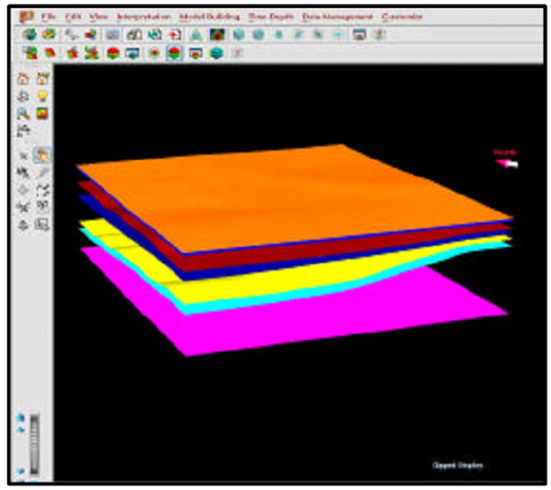

Fig-14: T- Surfaces

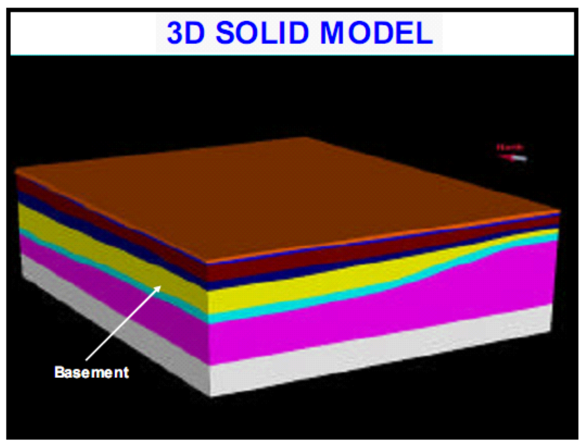

Fig-15: 3D Solid Model

The PSTM along-with the velocity section is shown in Fig-16.

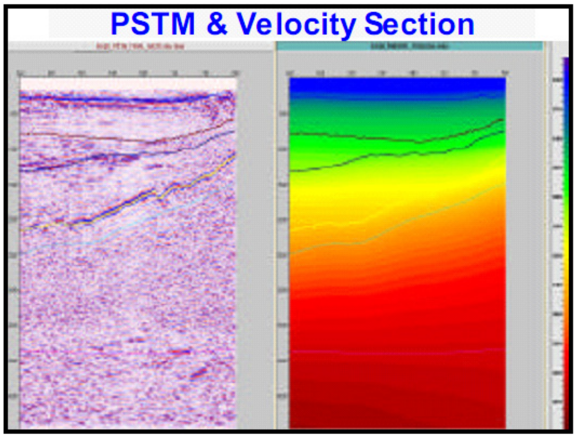

Fig-16: PSTM & Velocity Section

Improvement in Final Output (Stack)

Fig-17 & 18 shows the comparison of the old processed 2D section with a reconstructed line from the 3D volume along the same 2D line and shows the improvement in the stack section after PSTM. In the second figure, the basement configuration is clearly visible in comparison to the old section.

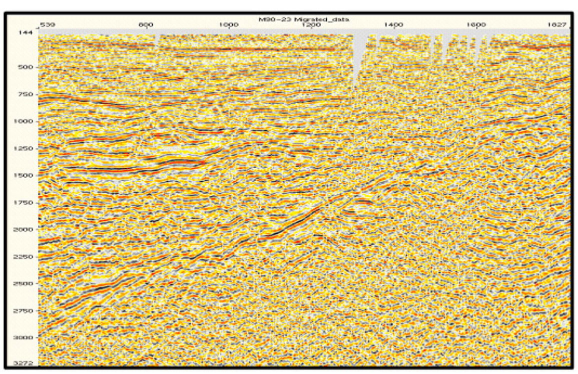

Fig-17 : Old 2D Section

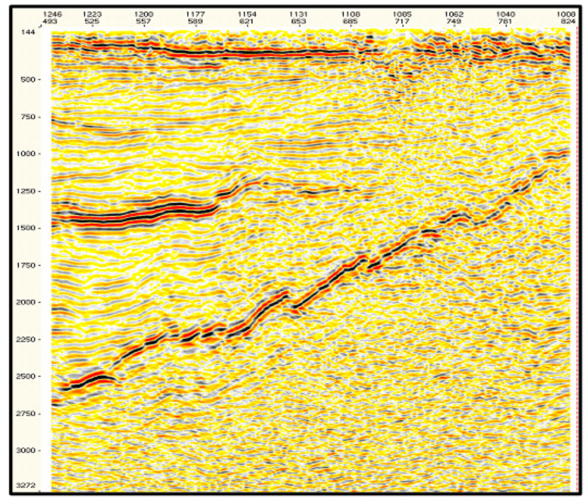

Fig-18: Corresponding section from 3D volume

Conclusions

In the earlier 2D vintages of the study area , the seismic sequences were not resolvable for proper interpretation. The new 3D seismic line along the said 2D section (Fig-18) 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.(Fig-18) . In addition, the data also brings out a few, better-defined strati-structural anomalies (Fig-19) suggestive of a drastic improvement in output data quality.

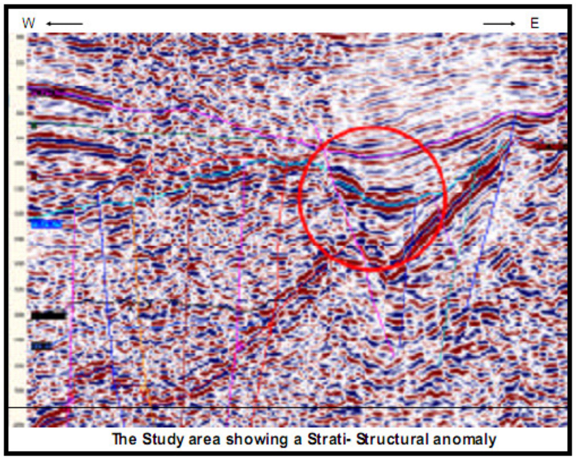

Fig-19: Strati-Structural Anomaly

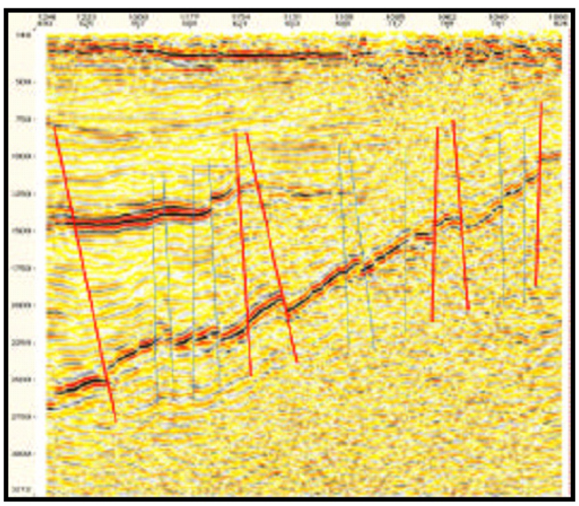

Fig-20: Interpreted Section

Thus, the processed 3D seismic data has resulted in a noticeable improvement in output data quality enabling better interpretation. A final interpreted section is shown in Fig-20.

A well drilled over the said strati-structural anomaly shown in Fig- 19 proved oil and gas bearing both from the Albian (Andimadam) Limestone pay (at the lower part of the anomaly) and also from weathered / fractured Granitic basement. This reflects that a well orchestrated / coordinated approach during API proved the sub-basin's worth, which has been hither-to accorded a very low prospectivity from hydrocarbon stand point.

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

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