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Multicomponent Seismic (3C) Data Acquisition – A case study from Oil India Ltd. operational area in Upper Assam Basin

K.L.Mandal*, K. Dasgupta, Dr. R. Dasgupta and A.K.Khanna
Oil India Limited, Duliajan.

Summary

Oil India Ltd. (OIL) has several old & matured fields viz. Makum-Hapjan, Jorajan, Nahorkatiya and Moran related to the upper Eocene -Oligocene Barail Group and Miocene Tipam group (within around 3000m depth) in Upper Assam Basin, India , wherein the reservoirs are at various stages of depletion. Apart from Tipam & Barail formation, late Miocene Girujan formation is also prospective in places. To sustain hydrocarbon production from these fields, it has been decided to arrest the declining production by finding un-swept/by-passed oil as Well as new hydrocarbon bearing sands within Girujan, Tipam and Barail formations, which are still remain undetected through conventional seismic.

In order to achieve the objective, OIL has decided to carryout Multi-component seismic survey in its fields for having superior subsurface image and improved reservoir model in terms of lithologic information, types of fluid present and presence of anisotropy & fractures etc.. A feasibility study has been carried out using Well log data & review of available seismic data of various fields in Upper Assam Basin to understand the suitability of the multicomponent in these areas. Based on the feasibility work, a 2D -3C survey has been initiated as a first phase of multicomponent seismic campaign for better imaging and understanding the main reservoir sand in the field area.

Introduction

Multicomponent seismic recording (measurement with vertical- and horizontal-component) captures the seismic wave field more completely than conventional P-wave techniques. Multicomponent surveying technique development has made it possible, the creation of converted-wave or P-S images. Multicomponent seismic survey is primarily being used world wide for determination of fracture density & orientation, gas identification, estimation of fluid content, investigations into quantitative saturation and pressure changes, providing another/better structural image, determining lithologic information and monitor reservoirs. In this paper a case study has been presented covering feasibility study over different producing oil and gas fields in Upper Assam to understand the suitability of the multi-component and field implementation of multicomponent survey (2D-3C) in areas of Upper Assam Basin.

Geological Background

Assam-Arakan basin is a polycyclic basin located in the North-Eastern part of India. The shelf part of the basin spreads over the Brahmaputra and Dhansiri valley, shelf to basinal slope part lies below the Naga Thrust and the basinal (geosynclinal) part is occupied by the Naga Schuppen belt and the Cachar-Tripura Mizoram-Manipur fold belts. This is a proven petroliferous basin. About 7 kms thick sediments ranging in age from Paleocene to Recent are present in the shelf part and a huge thickness of more than 10 kms sediments ranging in age from Upper Cretaceous to Recent is present in the fold and thrust belt. Eocene-Pliocene sequences contain potential source, reservoir and cap rocks. Around 115 oil and gas fields have been discovered in the basin. The Upper Assam Shelf part is predominantly a Tertiary Basin. Sediments of Paleocene/ Eocene age were deposited in shallow marine to marine environment in this basin. Regional tilt/uplift prompted widespread marine regressions with an increase in the supply of sediments to this part of the basin during Oligocene.

Geophysics Department, Oil India Limited , Duliajan, Assam, India. Email : klmandal@oilindia.in

Study Area

The study area is located in central part of OIL's operational area in Upper Assam Shelf Basin, at the southern bank of Brahmaputra River, in north-eastern part of India (Figure- 1).

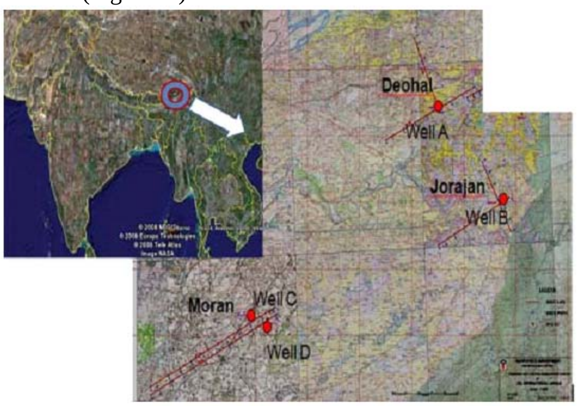

Figure- 1: Location map of the study area in Upper Assam Basin

Objective & Methodogy

As already stated many of the fields of Upper Assam are in the stage of depletion. There may be left over hydrocarbons in such fields. Moreover, there are other fields which are in different stages of development. The objective of this multi-component survey is to establish the technique for identifying the un-swept or the left-over oil in the matured or depleted fields as Well as the characterization of the producing reservoirs. The survey is also aimed at identifying and mapping shallow hydrocarbon reservoirs in the areas of survey.

In order to identify and rank the areas suitable for the multicomponent survey, a feasibility study is carried out. In this study, the data of several Wells with di-pole sonic have been analyzed. In this study, we present the analysis of Wells A, B and C pertaining to three different fields (Figure-1). The prospective Tipam and Barail groups are shallower in Well A. Eocene targets (Narpuh sands) are below 4000 m depths as encountered in two of the Wells B & C. The Barail sequence defined for Wells B & C includes inter-bedded sands, shales, and coals. In all these fields, the main producing formations are Barail and Tipam sandstones. Their permeabilities range from less than 7 millidarcies to 800 millidarcies, and porosities up to 30%.

We note that there are distinct S-wave velocity (Vs) anomalies in the Barail sands. Vs generally increases with sand quality. This is an important observation for the future use of converted (P-to-S) waves as the PS reflection coefficient is a function of the change in Vs across an interface. So, an increase in Vs in the Well logs, from overlying sediments to the sands, is an essential property for sand delectability from multicomponent data. Sands are further indicated by a lowered SP, low gamma ray (50 API), 30% porosities, lowered densities, resistivities between 10 and 20 ohms, and high Vs. In the plots (on a Vp versus Vs chart), hydrocarbon bearing sands are found below Vp/Vs=2 and below the mudrock line (Figure 2A & 2B). It is observed from dipole sonic logs of Well A that there is little difference between fast and slow shear waves near Well area (Figure 2C). This suggests small azimuthal anisotropy at this location. However, the area does have faulting and fracturing, so on a larger scale azimuthal anisotropy may be present. With the vertically layered strata, vertical transverse isotropy or variations of seismic velocity with angle from the vertical is expected.

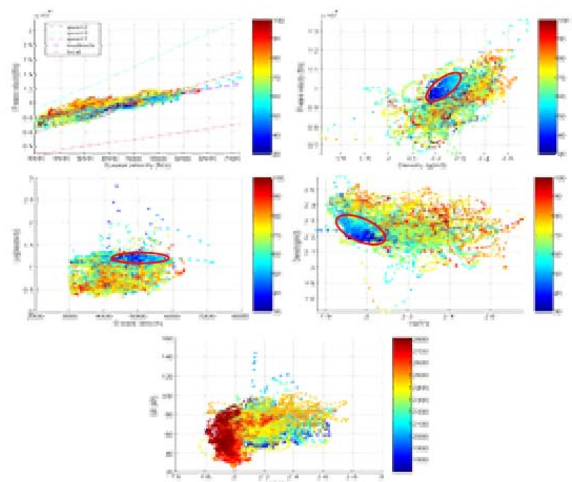

Figure 2A : Crossplots of logs from Well A (a)P- vs S-wave velocity, (b) P-wave vs density, (c) Resistivity vs S-wave, (d)Density vs Vp/Vs and (e) GR vs Vp/Vs. Colorbar indicates GR, except on (e) where it indicates depth.

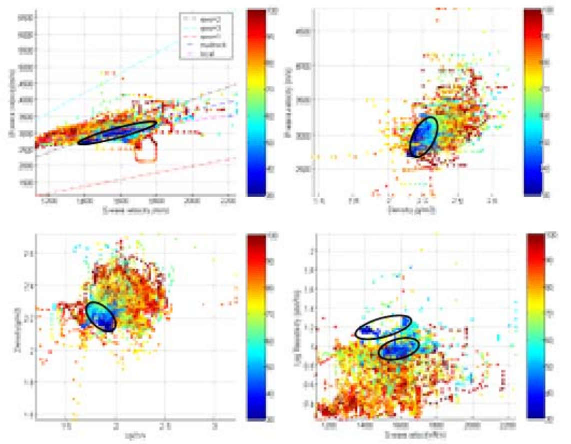

Figure- 2B : Crossplots for producing Well of nearby area of Well A, (a) P- vs S-wave velocity, (b) P-wave vs density, (c) Resistivity vs S-wave, (d) Density vs Vp/Vs. Colorbar indicates GR.

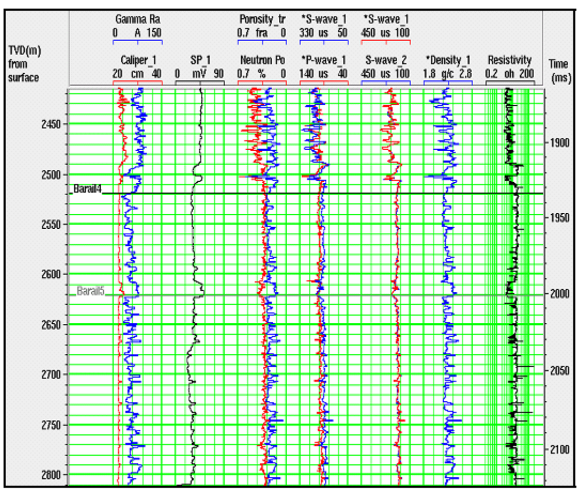

Figure 2C : Details of logs in the Barail 4 & 5 intervals Well A

Synthetic Seismogram

Synthetic seismograms were generated during feasibility study to see the responses of S-waves from the prospect horizons and to decide the survey design parameters. Three Wells, which had P- and S-wave sonic logs available, were used to generate PP and PS synthetic seismograms. None of the synthetic seismograms were deep enough to image the Eocene targets as sonic logs were not available for that interval. The surface seismic data indicate that there is a signal frequency band from about 10-60 Hz for the P waves. This suggest that PS frequency band may be expected from about 5-30 Hz. Thus, synthetic seismograms with sources wavelets in these ranges were computed.

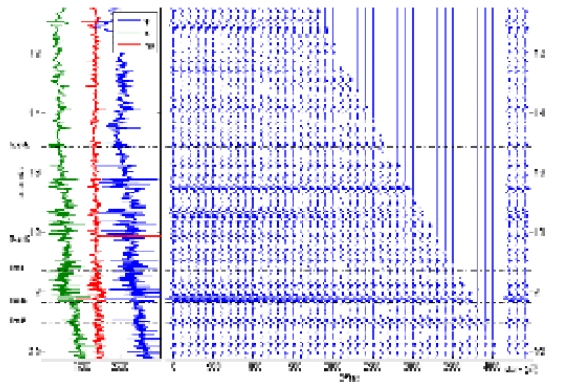

Figure-3A : PP gathers with NMO correction at Well A.

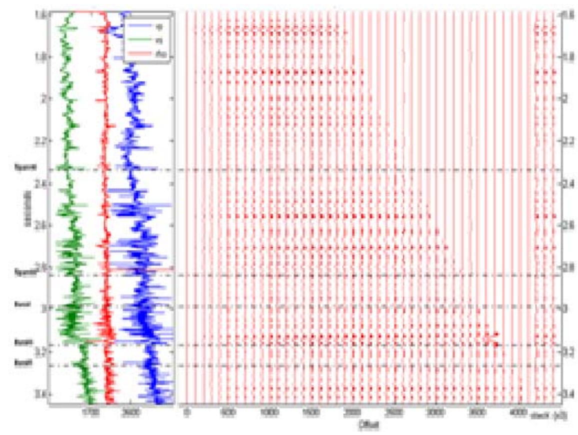

Figure- 3B : PS gathers with NMO correction at Well A

The PS synthetic seismogram from Well A show an amplitude increase with offset at the top of reservoir (Barail) sand **(Figure 3B)** , however, the same is not appearing on PP section **(Figure 3A)**. It is also evident that upto offsets of about 3500 m there are little or no changes in polarity, which suggests that an offset to depth ration of about 1.5 is reasonable. Synthetic seismogram results from the Well C and Well B are shown in **Figure-4A & B and Figure- 5A & B** respectively. It is noted that there does not appear to be major phase change at 3000m offsets at Barail level depths. Furthermore, the PS energy is arriving at about 3.0s.

The feasibility analysis shows that reservoir sands Barails have anomalous S wave velocity character that may be identified using converted wave methods. Because of the relatively shallow target depths and good S-wave sand responses, it was recommended to take up multicomponent seismic surveys in the areas which are ranked in the order Well A, B and C area as priority.

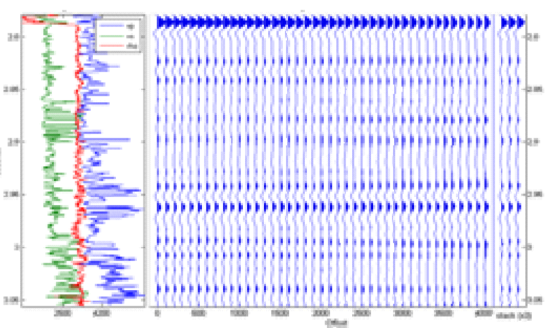

Figure- 4A : PP gathers with NMO correction at Well C

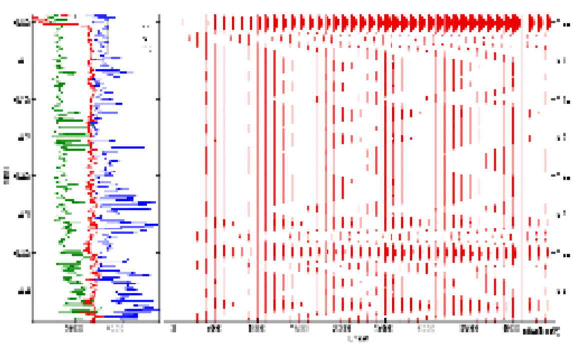

Figure- 4B : PS gathers with NMO correction at Well C

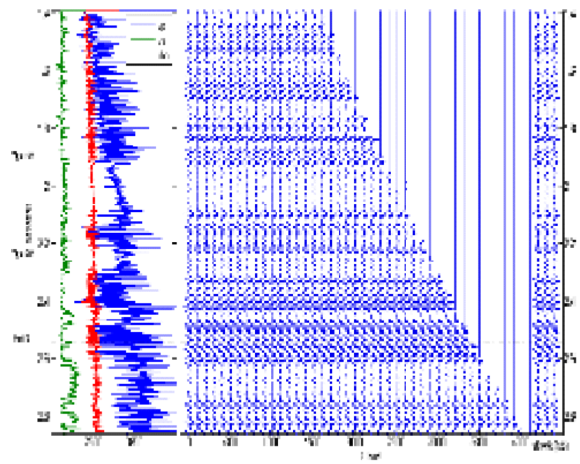

Figure- 5A : PP gathers with NMO correction at Well B

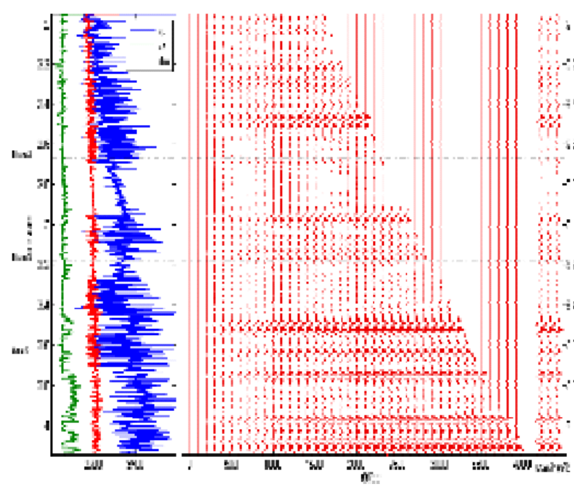

Figure- 5B : PS gathers with NMO correction at Well B

The Jorajan (Well B) and Moran (Well C) regions also have significant S-wave responses, but are relatively deeper and therefore more challenging. But due to operational constraints for time being, the area pertaining to Well C was taken up for multi- component seismic survey on priority basis.

Multi Component Seismic Acquisition in Well C Oil Field Area

Well C oil field is located in Moran District about 120 kms south west of Digboi Oilfield in Assam **(Figure-1).** Connecting these Wells (Well A, B, C & D), some specified 2D lines were proposed to critically observe the P and S wave characteristic, which facilitates to search new oil or gas bearing sand patches rather than the existing reservoir, if possible. Multicomponent Survey (2D-3C) was carried out using Sercel's E-428 XL recording instrument along with Micro-Electro-Mechanical Systems (MEMS) sensors for converted wave recording.

Data quality of Shear wave acquisition is major issue because the Micro-Electro-Mechanical Systems (MEMS) sensor are extremely sensitive to subtle noise and one should always maintain data quality of such order that distinctively interpretable layers could be correlated both in PP and PS domain. The major challenges in Shear wave acquisition are- orientation or alignment of all MEMS sensors to record Radial component in every ground station in an identical manner, maintaining proper receiver coupling with ground and maintaining good shot hole depth, charge size and shot hole coupling.

For this particular project, lines were oriented in such a way that it gives a good idea of directional property changes throughout the area in different possible direction and were connected with Wells for further Well to seismic ties. The length of the lines varied from 15 km to 40 km for mainly regional study purpose. The data requirement for this particular 2D-3C seismic survey is PP component, Radial component (PSv) and Transverse component (PS_H). To achieve the objective the sensors were planted in the ground keeping one horizontal component aligned along the line. This helped to record the data in Radial component (PSv) and Transverse component (PS_H). To plant the 3C geophones in a particular direction was a challenge at implementation level. A large numbers of skilled labour were required with hand compass to do this particular job meticulously. To make the jobs easy, an arrow pointing towards the direction of line on the higher side of increasing number of Ground station was marked and the persons were trained to align the MEMS receivers accordingly. However in some cases where this arrow mark was destroyed in field due to cultivation work or some other reasons, hand held compasses were used to align the 3C geophones. Dynamite was used as energy source as the surface topography is not suitable for vibrator movement in the area.

Maintaining good receiver coupling in hard surfaces is a challenge. To mitigate this problem, hand driven drilling machines were used to drill holes in the ground and then MEMS sensors were planted with proper coupling. The shot interval was kept twice the receiver interval. As S wave moves slower then P wave, the Vp/Vs factor is nearly 1.6 in the area. The recording length was fixed at 10 sec to enable shear wave data recording.

Results

The acquired 3C data sets are currently under analysis. Coherent energy is seen on the PP, PS H and PSV records Figure 6A,6B and 6C respectively. The dominant energy on P wave records is about 40 HZ , while on PS H and PSV is about 20HZ. We observe strong events around times 2400 3100 ms in P wave data **(Figure 6A)** & 4000-5000 ms **(Figure 6B & 6C)** on S wave displays, which may be associated with the Barails, the target reservoir sands in the area.

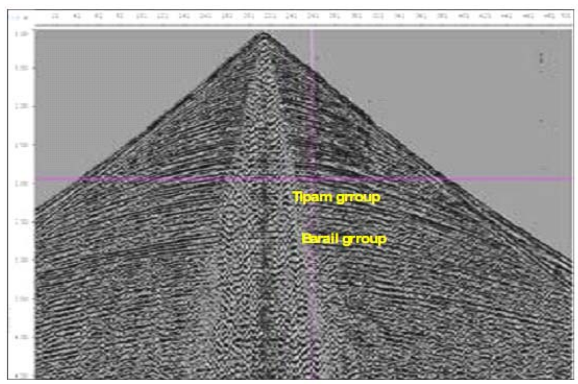

Figure- 6A: P wave component

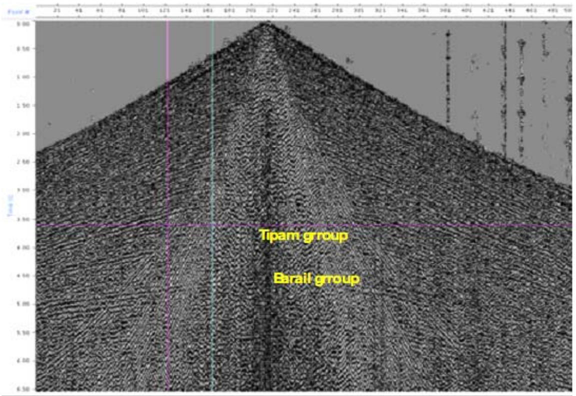

Figure- 6B: PSH wave component

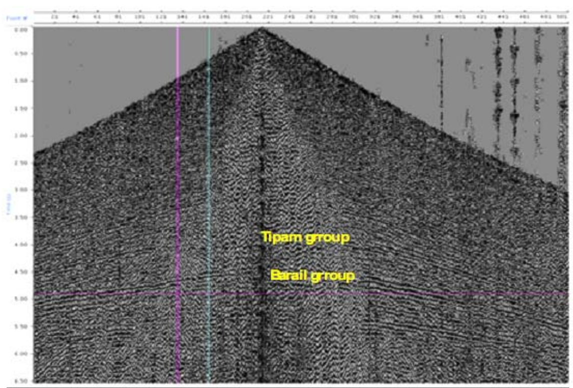

Figure- 6C: PSV wave component

Conclusions

The above pre survey feasibility analysis shows that reservoir sands Barails have anomalous S wave velocity character that may be identified using converted wave methods. Petrophysical analysis and synthetic seismogram modeling show the distinctive character of the reservoir sands. Recorded data adds confidence on that. The study also helped to convince the technical merit of applying this new technology in Well C field area. The full benefit of these new data will be realized only after the processing and interpretation of the acquired data. As on date we have already extracted the PP component from raw data and the resulting PP stacks shows exciting results with higher frequency content than conventional single component stack. We look forward to the further analysis of Shear wave components, which will result in further development and more widespread use of the new technology.

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