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Analysis of 3D far stack data and defining reservoir geometry, Variation/fluctuation of depositional environment in space/time and Fluid distribution in sandstone reservoirs of Daman formation of Late Oligocene age of Tapti Daman area/East of Diu arch.

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Abstract:

The Western part of Tapti-Daman sector covering part of Diu Arch has been explored widely based on the amplitude derived attributes and on interpretation of 3D seismic data. In the lower part of Daman formation, thick gas bearing sands have been explored which has no impact on amplitude anomaly whereas in upper part of Daman formation, high amplitude anomaly corresponding to the channel sand has been found water bearing. Lithological variation in Daman formation and its amplitude contrast has bearing in full stack 3D seismic data. The analysis of these amplitude changes indicates no impedance contrast in lower Daman part as high Impedance shale and high Impedance water/gas bearing sands is very low. In the upper part low impedance shale and high impedance sand shale impedance contrast defines the reservoir geometry. The reservoir distribution in Upper part of Daman is partially understood with its geometry but it is not completely/fully understood in the full stack 3D seismic data. In the lower part where the gas discoveries have been declared, reservoir characterization is a difficult task due to low impedance contrast. In the lower part, it has been found that the shales are dominantly silty in nature thus they lose fissility and have high impedance value. Sandstones are also silty in nature and have high impedance value. Analysis of Near, Mid and Far angle stack data has brought out the geometry of channel sands.

Far stack seismic data have been widely used to explore gas as they have AVO (Amplitude variation with offset) effect in silliciclastic depositional environment. In full stack sections, there is a phase reversal at the reflection from water sand gives way to gas sand reflection. When AVO model is generated by using average values taken from logs and input to the Aki-Richards equations, that illustrates trends of amplitude changes with increasing angle/offset. The AVO model indicates decreasing water sand reflectivity with increasing angle/offset, whereas the gas sand effectively brightens with increasing angle/offset. Thus far stacks is the best way to capture hydrocarbon signature in this part of the study area.

Introduction

Amplitude anomalies have been the significant tool for the exploration as bright spot/DHI for many years for the Geoscientist. This has proved to be important in some places and in some formations whereas it has proved fatal at some places. Since it is one of the quick look interpretation it is still adopted by Geoscientists. However, validation of the anomalies is done through different petrophysical analysis. Tapti Daman sector in the Western offshore basin (Figure-1) has been explored widely based on the Amplitude analysis.

Late Oligocene Daman formation has been explored in this basin from 2D seismic data to 3D seismic data. The amplitude anomaly which is not applicable for the upper part of Daman formation has proved commercially viable for lower part. The Western part of Tapti Daman sector covering part of Diu Arch (Figure-2) has been explored widely based on the amplitude driven exploration. High Amplitude anomalies depicting presence of thick channel sand proved to be water bearing after drilling. The shales within the Daman formations are taken as low impedance shale and water bearing sands as high impedance sandstones.

An attempt has been made to analysis the lithology and their impedance in the western part of Tapti Daman sector on the eastern flank of the Diu arch. In the western part of Tapti Daman sector and eastern flank of Diu Arch the lower part of Daman formation having thick gas bearing sand 15-18m has been explored which has no much impact on amplitude anomaly whereas in upper part of Daman formation high amplitude anomaly corresponding to the channel sand has been found water bearing.

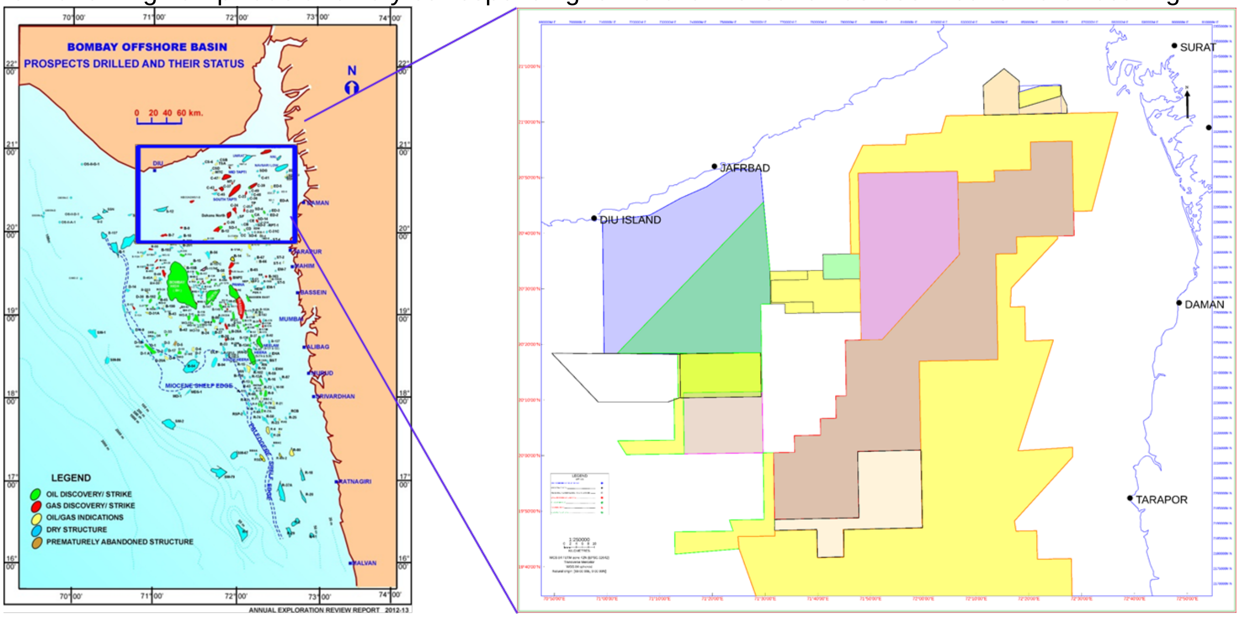

Figure-1: Location Map

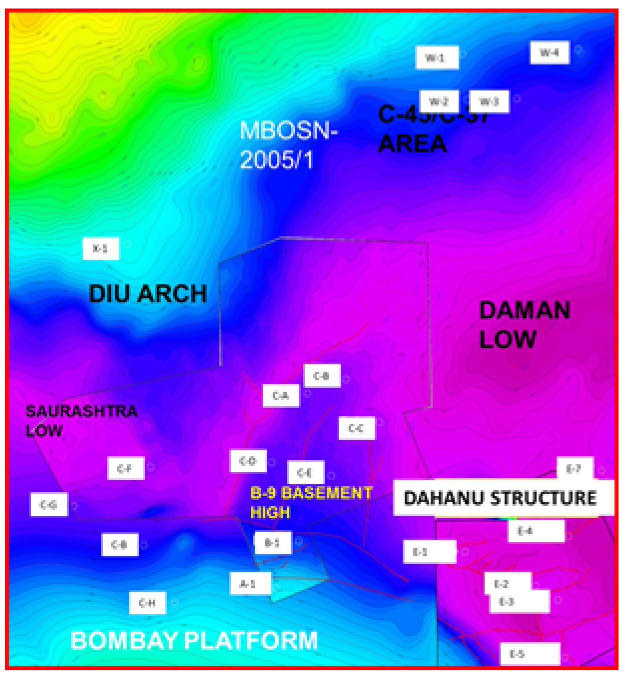

Figure-2: Time relief map on top of Mahuva/Heera formation

Cross plots of well log data have been attempted and the shales of the area are analyzed in greater detail. It has been found that the shales are dominantly silty in nature thus they lose fissility. Sandstones are also silty in nature and at some places loose as they pose problems in testing. Sand incursion is also a problem in testing and well completion. The analysis of the impedances of the lithology and pay sands from logs are then compared with seismic data. The analysis suggests that the shale in the lower part of Daman formation are predominantly high impedance shale which are close to Gas bearing sands. Thus, it becomes difficult to differentiate the Gas bearing sands and shales. The shale in the upper part of Daman formation are clean and devoid of silt lower impedance. Validation of windowed attributes by AVO analysis and other advanced seismic methods are done.

Tectonic Elements

The block is within the continental shelf, situated on the rising flank of the Saurashtra Homocline. In northwest and west, Diu Arch is present as a NNW-SSE trending SSE plunging basement high. The Diu depression is to the south and Daman Low to the southeast. The Diu Arch laterally flattens out in the southwestern part of the block. The region has undergone Rifting followed by passive continental margin tectonic history with the structural style being dominantly controlled by basement faults. However, inversion tectonics has also played a major role in modifying the existing structural style. The basement architecture of this area has been evolved by the process of Rift-Drift of the Indian Plate. Extensional stresses that were active during the rift phase created number of Horst-Graben features associated with normal faults in the Dharwarian trend i.e., NNW-SSE. A major strike slip fault trending ENE-WSW divides the area into two parts with homoclinal dips towards the north of this fault and inversion structures towards the south of this fault.

Stratigraphy

Generalized stratigraphy of the area is given in Table-1. All the wells in and around the Block were studied in detail with respect to their cuttings, core data and hydrocarbon shows for understanding the stratigraphy of the block

AGE		Seismic Horizon	FORMATION	LITHOLOGY
Recent			Chinchini	Dominantly Clay/ Claystone, though coarser clastics are expected towards the northwestern part.
Pliestocene				
Pliocene	Late			
	Early			
Miocene	Late			
	Mid	H$_1$A	Tapti/ Bandra	Dominantly shale with Siltstone bands in to the northeast and Limestone bands developing to the southwest.
	Early	H$_1$C	Mahim	Shale with few Siltstone.
Oligocene	Late	H$_3$CGG	Daman/ Alibag	Dominantly shale with sandstone beds with few thin coal layers towards the east and limestone beds towards the west.
	Early			
		H$_3$G	Mahuva	Dominantly shale with limestone beds.
Eocene	Late			
	Mid	H$_3$B	Diu	Shale, siltyshales.
			Belapur	Calcerous shales.
	Early			
		H$_4$	Jafarabad/ Panna	Shale and limestone (wackestone) towards Diu arch and sandstone with lignitic coals towards Tapti-Daman area.
Paleocene	Late			
	Early			
Cretaceous	Late	H$_5$	Deccan Trap	Basalt, weathered basalts.

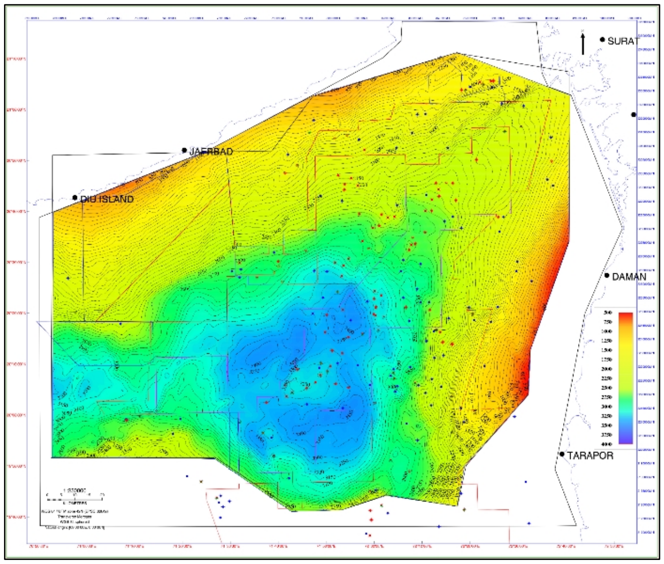

Figure-3: Regional time relief map on top of Panna Formation

Why far stack data and its role in Hydrocarbon Exploration:

Far stacks have been widely used to explore gas as they have AVO (Amplitude variation with offset) effect. In full stack sections, phase reversal at the reflection from water sand gives way to gas sand reflection (Figure-4). The AVO model generated by using average values taken from logs and input to the Aki-Richards equations, illustrates trends of amplitude changes with increasing angle/offset. Generally the AVO model indicates decreasing water sand reflectivity with increasing angle/offset, whereas the gas sand effectively brightens with increasing angle/offset. Thus far stacks may be best way to capture hydrocarbon signature.

However, this cannot be used as general concept and care needs to be taken. The optimal angle/offset for imaging fluids is effective within the range of seismically acquired angle/offset. AVO as DHI are most commonly seen where fluid compressibility can have a significant effect on whole rock compressibility. AVO is more significant in relatively shallow unconsolidated sand or partially consolidated sand but not exclusively. In good consolidated sand, the fluid tends to make a smaller contribution to whole rock compressibility that’s why AVO effects are usually subtle. It is to be noted that seismic amplitudes are greatly affected by geological and spatial context.

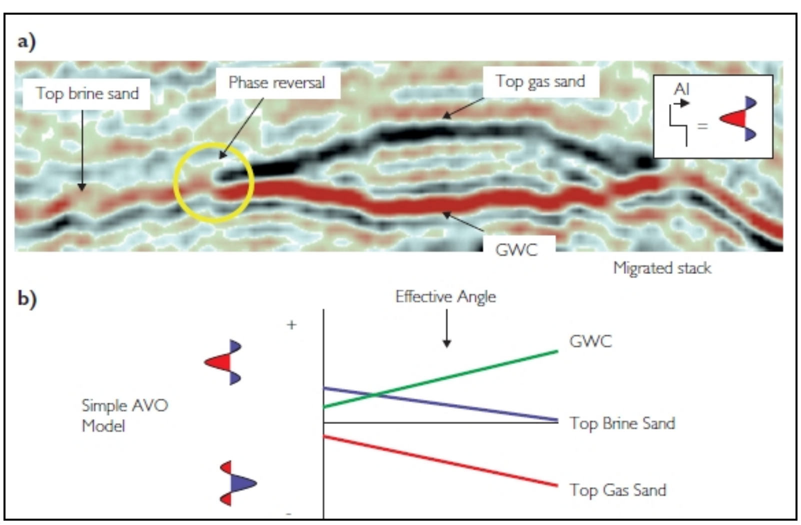

Figure-4: A bright spot on migrated stack display related to presence of gas; (a) migrated stack display (SEG-Y reverse polarity) courtesy Rashid Petroleum Company; (b) Schematic rock physics model.

Reservoir Geometry

The log correlation (Figure-5) of wells for Daman formation has been carried out and calibrated with the Far stack seismic data.

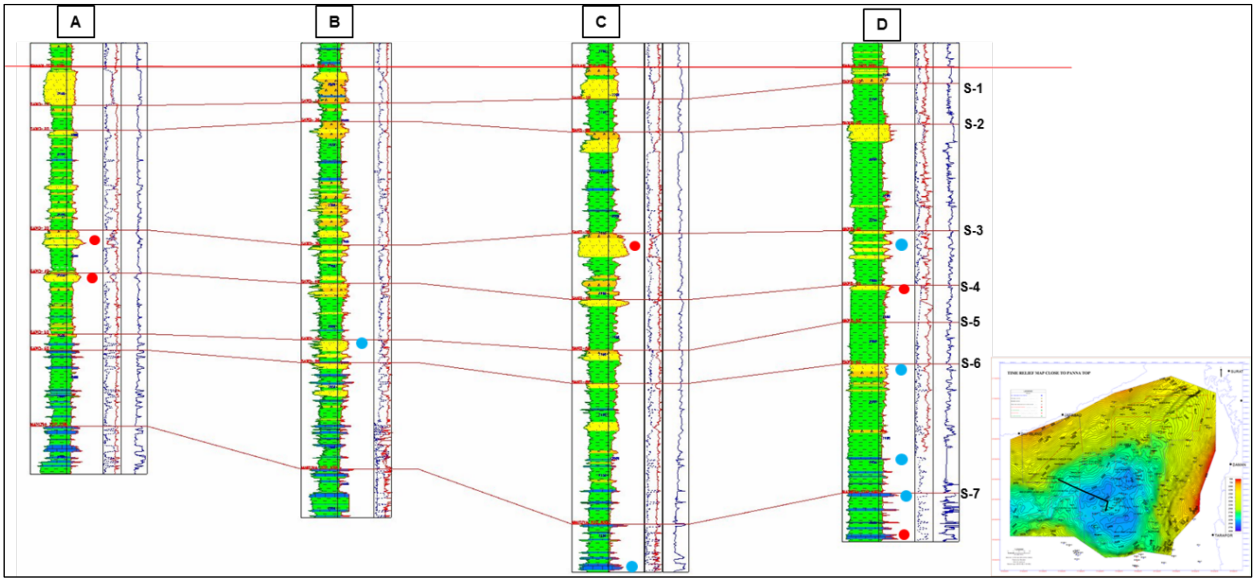

Figure-5: Log Correlation of the wells for Daman Formation.

The youngest pack of channel sands have interplay of older and younger channels in space. Older and younger channel geometry has been defined in the amplitude map. Parallel and orthogonal relation of the channel to the present-day structure define the entrapment condition. The geometry of the middle sand is clearly defined and meandering channel of delta plain area from north reaching to knuckle point and further to upper delta plain and lower delta plain is also defined. The bifurcation of channel from knuckle point in the South east and another in the southwest direction has been defined (Fugure-6). The upper part of channel being orthogonal to the contour has less possibility of stratigraphic entrapment conditions whereas the bifurcated sand running parallel to the structure and further to down dip has potential entrapment condition.

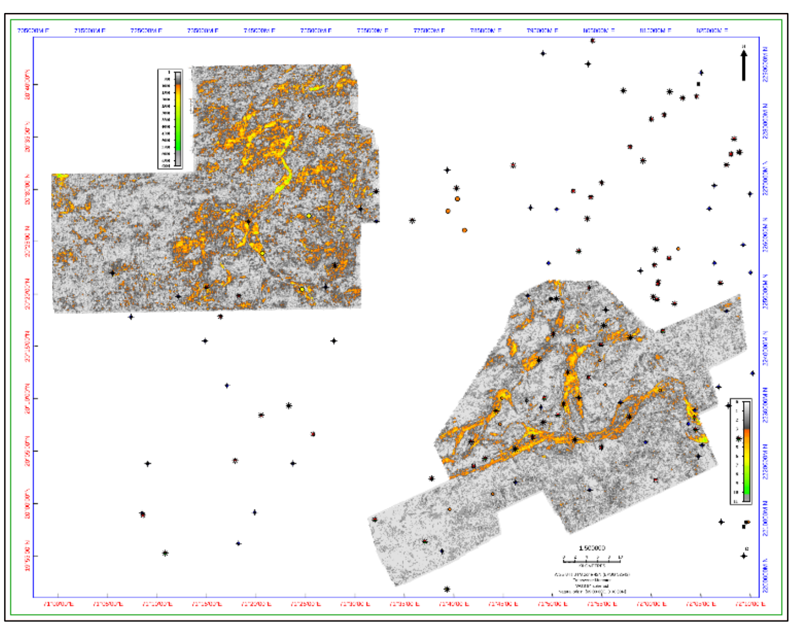

Figure-6: Horizon slice of the Far stack seismic data for Middle sand pack of Daman formation in Tapti Daman area and East of Diu arch indicating the geometry of the sand

Variation/fluctuation of depositional environment:

In the older sequences of Daman formation highly reworked tidal channel and bar sequences with channel cut and fill structures giving proper stratigraphic entrapment condition has been observed in the far stack data.

The geometry of the middle sand is clearly defined and meandering channel of delta plain area from north reaching to knuckle point and further to upper delta plain and lower delta plain is also defined.

On analysis of the three sand packs it has been found that oldest channel is a part of Tide dominated channel and bar complex which was getting highly reworked as observed in the cores of the wells where burrows are predominant and highly reworked sandstone has been seen (Figure-7).

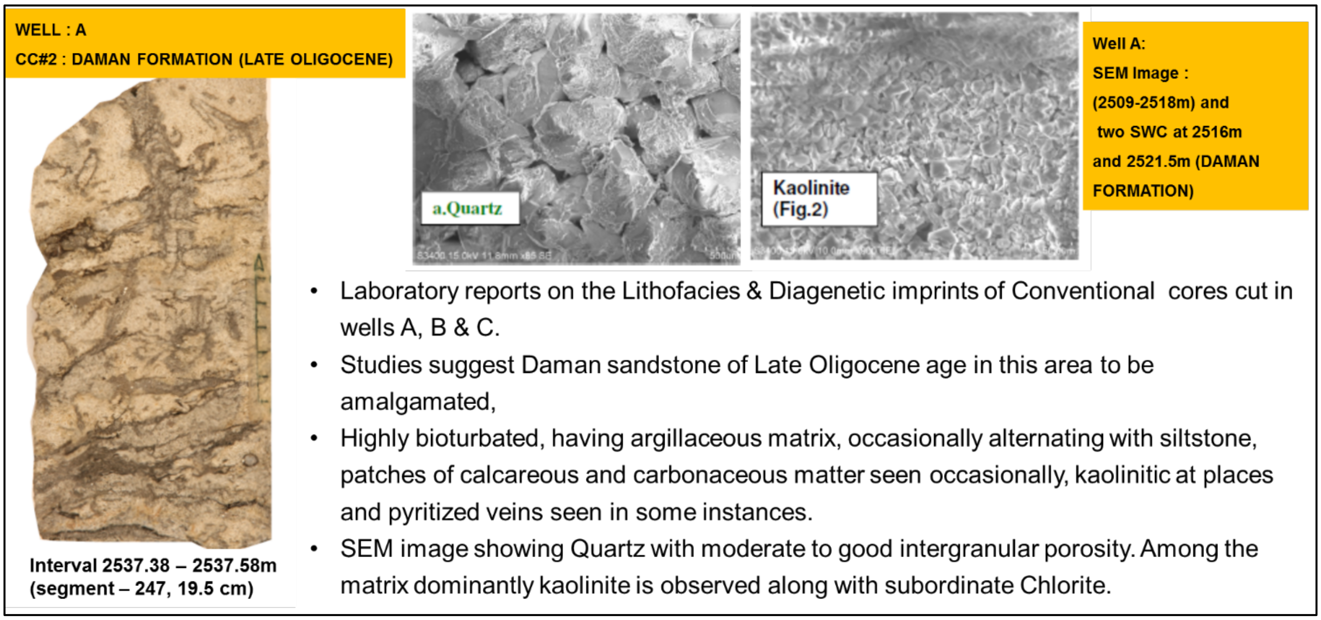

Figure-7: Detailed core and sidewall core analysis

This as a part of initiation of forced regression where the proximal shoreline with near flat topography. The middle part is deposited during the peak forced regression and the geometry of the middle pack and core analysis suggest that this pack is dominated by tide dominated channel levee complex with no mouth bar deposition due to high reworking by tides and waves. The youngest pack of the channel is deposited after a flooding surface when the transgression dominated. The deposition of sand is mainly controlled by tidal channel. No tidal bars are observed due to highly reworking tides.

Fluid distribution:

The amplitude contrast in the far stack data has been taken as DHI as these amplitudes are very close to the discovery wells where thickness of pay sand are less compared to the cut and fill structures observed in the seismic. The calibrated wells which are water bearing do not have amplitude contrast. The detailed analysis of impedances of gas bearing sands and lithology has been carried out (Figure-8). Intercept v/s gradient analysis clearly bring out the fluid distribution from the analysis (Figure-9).

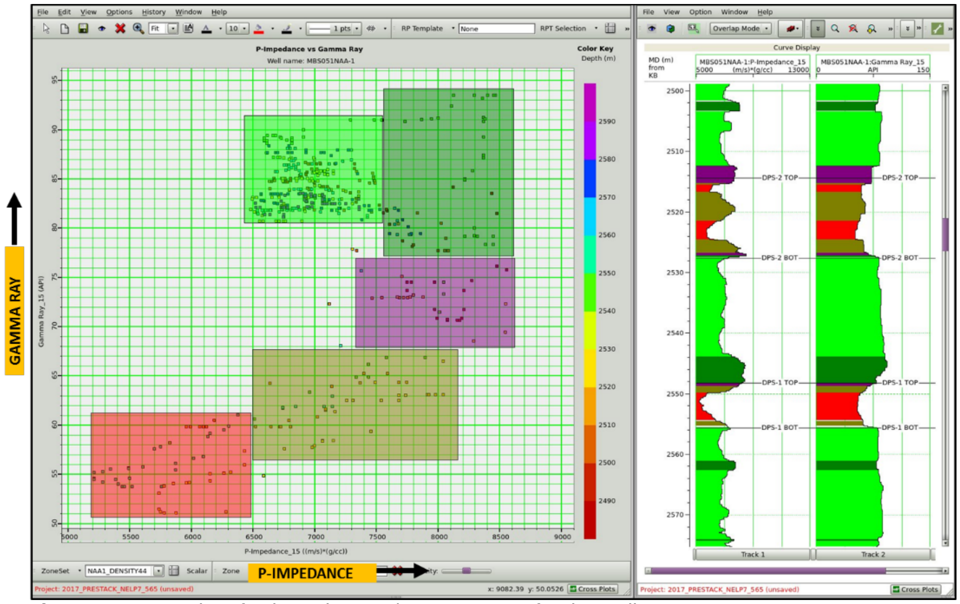

Figure-8: Cross plot of P-impedance v/s Gamma ray for the well-B

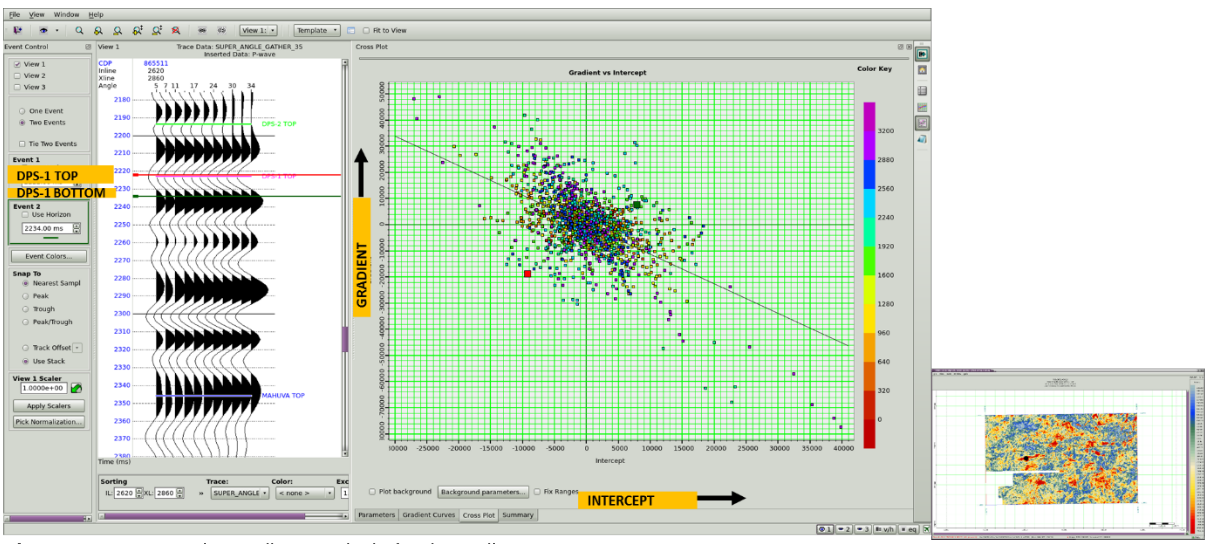

Figure-9: Intercept v/s Gradient analysis for the well-B

Conclusions:

1. The analysis of Far stack data and its comparison with Full stack and Near stack 3D seismic data helps in defining reservoir geometry, Variation/fluctuation of depositional environment in space/time and Fluid distribution in sandstone reservoirs of Daman formation of Late Oligocene age of Tapti Daman /East of Diu arch area.
2. In the older sequences of Daman formation highly reworked tidal channel and bar sequences whereas The geometry of the middle sand is clearly defined and meandering channel of delta plain area from north reaching to knuckle point and further to upper delta plain and lower delta plain is also defined.
3. The relations of the channels and bars are clearly established.
4. The amplitude contrast in the far stack data has been taken as DHI as these amplitudes are very close to the discovery wells where thickness of pay sand are less compared to the cut and fill structures observed in the seismic.
5. The calibrated wells which are water bearing do not have amplitude contrast. Intercept v/s gradient analysis clearly bring out the fluid distribution from the analysis.

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