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A Case Study on Log Property Mapping in Ramnad Sub-Basin for Better Understanding the Nannilam Reservoir Distribution and Risk Reduction in Exploration.

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Summary

Ramnad sub-basin, developed betweenPattukottai- Mannargudi ridge on the NW and Mandapam Delft horst on the SW, is situated in the southern part of Cauvery Basin, India (Fig: 1). The Nannilam reservoir sands of Coniacian-Campanian age in Ramnad onland area is the main producer. Two high gamma ray peaks mark the flooding surfaces within the Nannilam Formation and the lower gamma peak is identified as MFS (Maximum Flooding Surface) (Fig. 2). Nannilam-Sand-A (Sand-A) and Nannilam-Sand-B (Sand-B) are developed below and above the MFS respectively. The present study is mainly based on well data and the objective is to evaluate these sands in respect to their depositional settings and to understand the areas of better reservoir distribution. This would help in further exploration / exploitation. For this purpose, maps of log signature & petrophysical properties of these sand units along with relevant geoscientific data of all the wells in this area have been analysed.environment, and the spatial variation of their petrophysical properties. For each of the sand units, log property maps viz. gross & net reservoir thickness & their ratio, porosity & porosity-thickness (Φ×h) and water saturation (Sw) map have been generated and analysed. Surface relief map at the base of Nannilam Formation has also been prepared. Besides, the average impedance of sands has been computed and map generated to study the impedance variation. The impedance contrasts of the gas & water bearing sections of the reservoirs and that of the shales overlying and underlying it have been analysed.

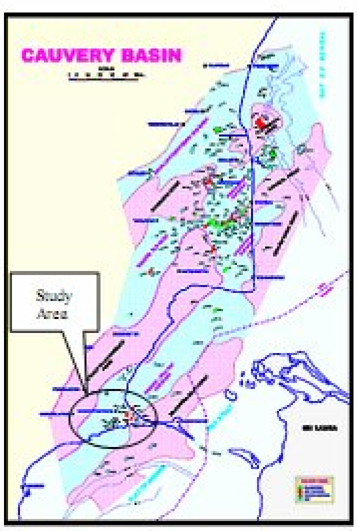

Figure 1: Cauvery Basin Map showing study area

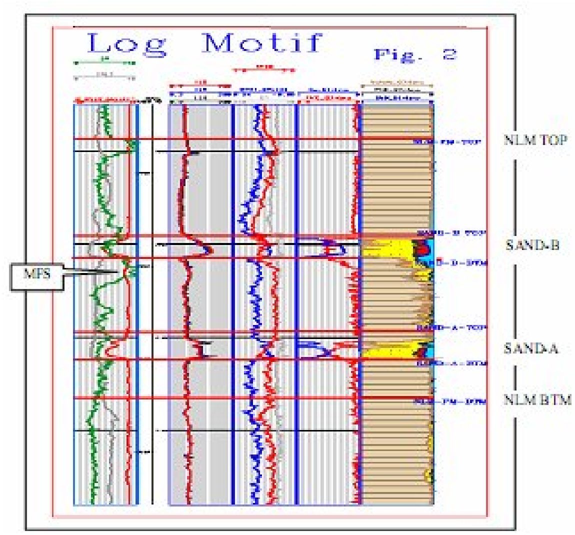

Figure 2: Log motif showing different sand units. Green & red traces in 1st track are GR & SP log; 2nd & 3rd track shows resistivity & porosity logs; 4th & 5th track displays computed porosity, Sw logs & lithology with fluids respectively

The study covers a good spread of wells in onland part of Ramnad sub-basin which constitutes four main fields viz. Periyapattinam (PP), Perungulam (PE), Ramanavalasai (RV) and Kanjirangudi (KJ) where 12 exploratory wells out of 29 have encountered commercial gas. Another hydrocarbon strike was in Palk-Bay-Shallow area i.e. well PBS-A. A total of 45 exploratory wells and 3 development wells have been drilled in the study area out of which 43 well data have been analysed for this study.

This study has clearly brought out distinct differences between different sand bodies, their possible depositional environment, and the spatial variation of their petrophysical properties. For each of the sand units, log property maps viz. gross & net reservoir thickness & their ratio, porosity & porosity-thickness (Φ×h) and water saturation (Sw) map have been generated and analysed. Surface relief map at the base of Nannilam Formation has also been prepared. Besides, the average impedance of sands has been computed and map generated to study the impedance variation. The impedance contrasts of the gas & water bearing sections of the reservoirs and that of the shales overlying and underlying it have been analysed.

Introduction

With the discovery of thick gas column in Kanjirangudi field, exploration activities have been intensified in Ramnad area. The Nannilam reservoir sands of Coniacian-Campanian age are of main interest. The present understanding of the reservoirs is that they are mostly deposited through debris flow (Ref. i). The biostratigraphic study mainly based on cutting samples indicates that they are deposited under 150-300m bathymetry while gamma ray spectroscopy on cores suggests shallow marine deposits (Ref. ii). However, characterization of this promising reservoir would help in formulating effective delineation and development of the established pools. Most of the successes are from the structural traps bound by west southwest to east northeast trending major fault and the north-south faults. These faults are the migration fairways.

There are surprise failures that pose real challenge to exploration. The exploration history of this sub-basin revealed the complexity of reservoirs, hydrocarbon migration and entrapment. One major problem is that even the thick gas sands do not stand out on the available seismic data. Exhaustive use of drilled data in mapping of reservoir characteristics helps in better understanding of spatial distribution of better reservoir facies. Figure 3 shows the west to east correlation of Sand-A and Sand-B.

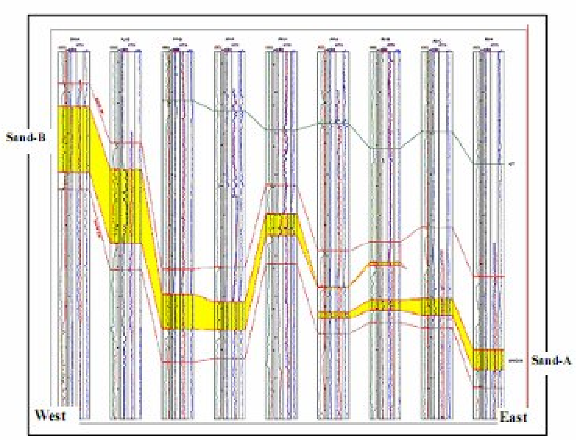

Figure 3: Log correlation from west to east.

Methods

Methods involving data processing, identification of litho-units and analysis procedures are elaborated below:

(A) Data Processing:

- Reviewing and editing petrophysical analysis of logs of all the wells in Landmark project and creation of different lithological units in Petroworks based on log marker.
- Generation of acoustic impedance curves using density and sonic logs.
- Carrying out petrophysical evaluation of logs and summing up of average reservoir parameters like gross & net thickness, net-reservoir-to-gross-thickness-ratio, porosity, porosity-thickness (Φ×h), impedance etc. followed by review vis-à-vis other geo-scientific data and laboratory reports.
- Mapping of reservoir attributes and analysis.

(B) Identification of different litho-units:

Following postulations are made so as to have broader and simpler litho-units:

- The entire Nannilam Formation is characterized by high gamma count. The upper gamma peak is considered as Nannilam Formation top whereas the base (the top of Kudavasal shale) is marked by fall in gamma counts.
- Nannilam Sand-A and Sand-B are developed below and above lower MFS respectively.

(C) Basis of Analysis:

- Log signature along with other geoscientific data have been used to indentify the depositional setting of the sand bodies. In Ramnad area the SP development is very good and manifests the grain size variation. Base line shifted SP logs have been used for identification of unique features of the sand bodies (e.g. fining / coarsening trend) as reflected on log signature maps. Since the sands are radioactive, Gamma Ray log could not be used for this purpose. However, Gamma Ray logs in shale sections helped in identification of major transgression and regression cycles.

- Log property maps have been used to analyse the reservoir distribution. The available pore volume is judged through the porosity-thickness (Φ×h) maps.

- Acoustic characteristics of gas & water bearing sands and vis-à-vis shales have been evaluated through its impedance values.

Observations

The salient observations are as follows:

Nannilam Formation & Reservoirs:

- Onset of transgression is noticed at the base of Nannilam Formation. The surface relief map at its base is found to be parallel to northeast-southwest paleo shoreline with a rising trend towards north-west (Fig. 4).

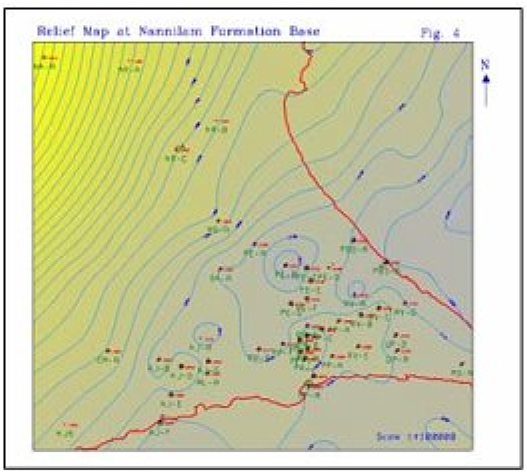

Figure 4: Surface relief map at Nannilam Base. Yellow colour indicates shallow area.

- Two prominent flooding surfaces, which are marked by high gamma ray peaks, are noticed within this formation. Lower peak is identified as MFS (Maximum Flooding Surface). Two main reservoirs viz. the older Sand-A and the younger Sand-B, are developed below and above the MFS (Fig. 2). Sand-A is aligned in the NNW to SSE direction along the present northern shore line. Sand-B in KJ-PP area is aligned in E-W direction along the present southern shoreline (Fig. 5 & 6).

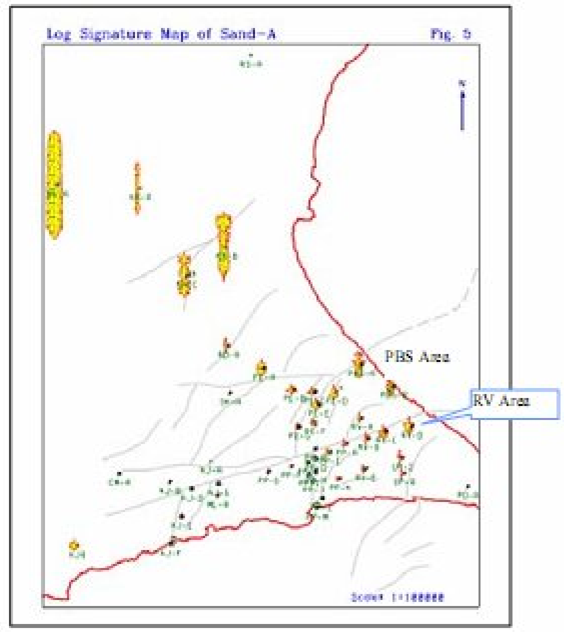

Figure 5: Log signature map of Sand-A

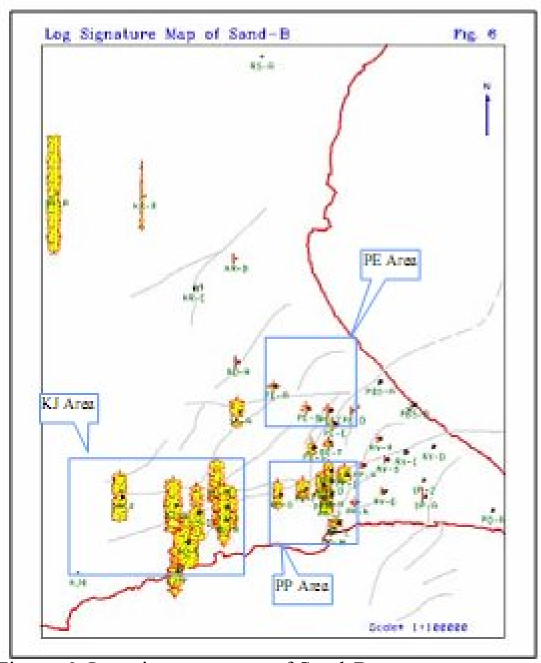

Figure 6: Log signature map of Sand-B

- Grouping of the sands based on time equivalence helps in visualizing the spatial variation of sand property through a common map. Sand-A is deposited at the early stage of transgression and developed mainly in NK, KR, PE, RV & PBS area. Sand-B is dominantly present in NK, KR, KJ, PP & PE area. Subsequent analysis reveals that Sand-A in PE area is different to that in KR, PBS, RV area. Similarly Sand-B in PE area is different to that in KJ & PP area.

Sand-A:

- Distinct differences in log motif are noticed in different areas within the equivalent sands. Both Sand-A & -B in PE area are exhibiting a distinct fining up sequence which suggests that these are deposited in a channel setup corroborating laboratory studies (Ref. iii). Existence of a Paleocene channel in PE area is evident on seismic data (Appendix-i). All these observations lead to believe that the same channel set up might have been present in PE area at the Coniacian-Campanian age facilitating the deposition of Nannilam sands.
- In KR, PBS, and RV area, Sand-A shows a coarsening up signature and therefore, it is different from the equivalent sand in PE area which shows fining upward trend.
- Log signature of Sand-A in wells KR-B, PBS-A, PBS-B & RV-D (Fig. 5) and seismic correlation (App-ii) also suggest that the provenance is in northwest direction.
- Spatial variation in reservoir quality of Sand-A in PE area is depicted through net reservoir thickness, porosity & porosity-thickness maps (Fig. 7, 8 & 9). It appears that the well positions are possibly in different parts on the channel. Average porosity is maximum (21%) in well PE-E, which falls to 13% in PE-F towards south where thickness also comes down and pinches out in well PE-G. Porosity marginally dropped to 19% in well PE-A in the northwest from PE-E but the thickness increase. The (Φ×h) map shows better reservoir trend towards PE-A suggesting that the well PE-A might be on the channel axis.

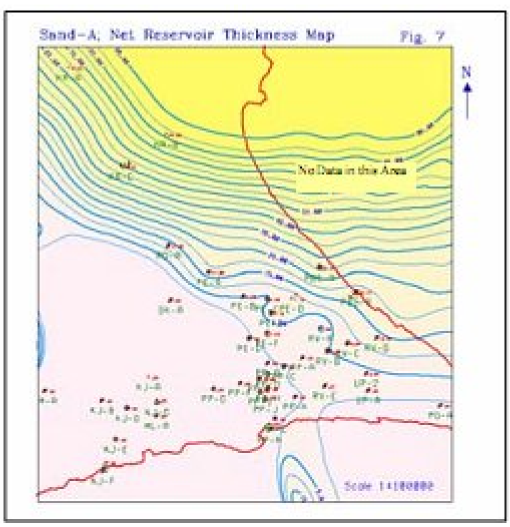

Figure 7: Net reservoir thickness of Sand-A. Yellow represts higher values.

- The (Φ×h) map in RV area suggests development of better reservoir and hence higher prospectivity towards ENE of RV area (Palk-bay area). Maximum porosity is 21 to 22% in wells RV-B & C.

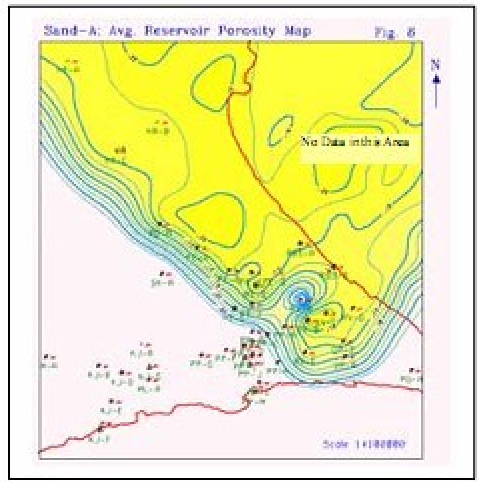

Figure 8: Average Porosity Map of Sand-A which pinches out south-westward. Yellow shows better reservoir facies.

- Reservoir quality deteriorates in the vicinity of wells RV-A, PP-A, PP-C and also towards Uchipuli (UP) area.

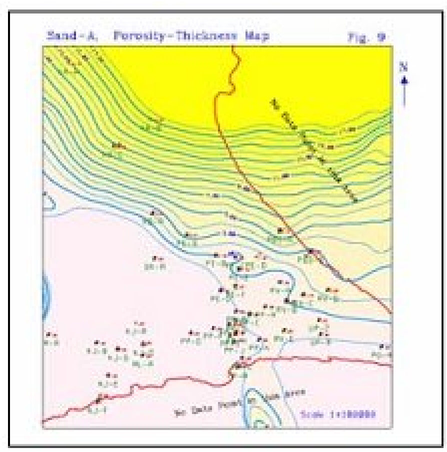

Figure 9: Porosity-Thickness Map of Sand-A

Sand -B:

- The younger Sand-B is very thick in KJ-PP area. The spread of this reservoir is demonstrated in Fig. 6. This sand is the main producer in KJ, PP and PE area. The thicker part in wells NK-A & KR-A is devoid of hydrocarbon. As because it is more prospective in the central and eastern part of Ramnad sub-basin, the study is confined to this area. Log correlation from west to east is shown in Fig. 3.
- The log signature map (Fig.6) shows blocky and serrated nature in KJ & PP area suggests stack of sand bodies deposited through mass flow mechanism. The blocky nature indicates possibly a higher rate of depositional compared to that of subsidence.

- The fining up nature of the equivalent sand in PE area indicates deposition in channel set up hence it appears genetically different from that in KJ-PP area.
- Sand-B is probably deposited in a regressive cycle that occurred in between two flooding events. The depositional trend is east-west parallel to the present southern shoreline. The thickness falls from north-west to eastward i.e. from NK & KR to KJ and PP area beyond which the sand pinches out. Therefore, the input appears from north-west. The net reservoir thickness map demonstrates the distribution pattern (Fig. 10).
- High porous zones (around 30%) are observed in Sand-B in Kanjirangudi area while the average value is in the range of 20 – 23%. In Periyapattinam area, average porosities are in the range of 19-24%. In the flank of Periyapattinam field, porosity reduces to 15% as shown in Fig. 11. Porosity-Thickness map (Fig. 12) depicts better reservoir development at the crestal part of KJ area. In PP area too improvement in reservoir quality is seen at the central part.
- North-westward from KJ area, presence of good reservoir is evident which may be explored at a favorable structural position.

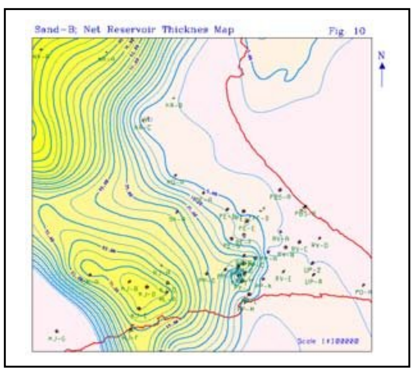

Figure 10: Net Reservoir Thickness Map of Sand-B

- In PE area average porosity is 17-25% but it reduces to 12% towards south in well PE-G. North-west of PE-E, reservoir quality marginally deteriorates. The sand pinches out east of PE area.

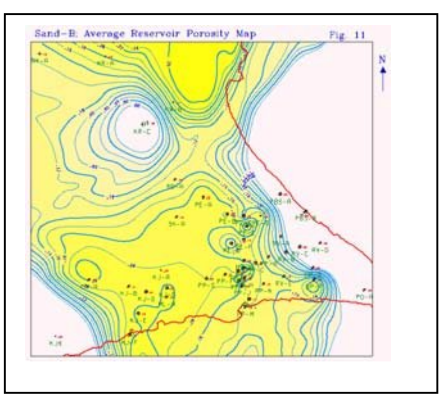

Figure 11: Porosity Map of Sand-B

- In Sakkarakotai (SK) & KR area good reservoir quality persists except in the vicinity of well KR-C where this sand is not developed.
- Water saturation maps (Fig. 13 & 14) of KJ & PP-PE wells show minimum value (23%) in well KJ-D. The gas saturation trend shows a north-south alignment (KJ-E to KJ-D & PP-I to PE-E). It is, thus, possible that the north-south faults might have acted as the main fairways for hydrocarbon migration to structurally favorable locales.

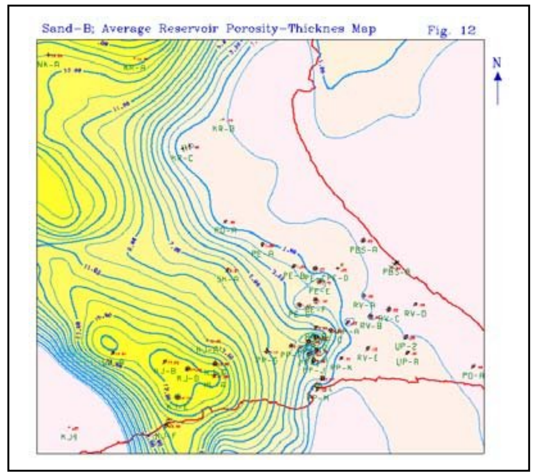

Figure 12: Porosity- Thickness Map of Sand-B

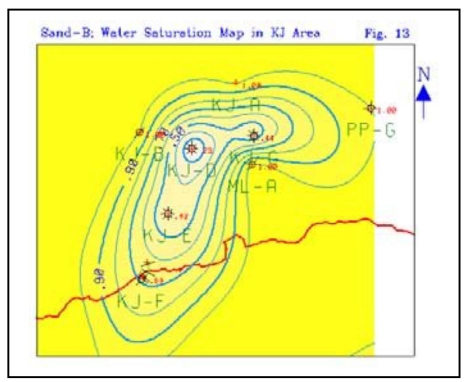

Figure 13: Water saturation Map of Sand-B in KJ area. Yellow colour represts high water saturation.

- Average impedance maps of both the sands exhibit relatively lower values in and around gas wells as compared to that in dry wells. Here example has been cited for Sand-B through Fig. 15 and 16 which shows average impedance map and crossplot indicating its variation with water saturation respectively.
- Contrast in impedance of gas & water bearing sections and adjacent shales exist excepting some overlaps. Table-1 shows the range for gas and water sands in different areas. Gas sand in PE area shows higher impedance as compared to that in KJ-PP area.

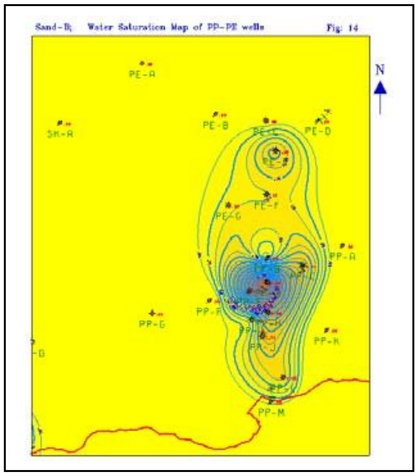

Figure 14: Water Saturation Map of Sand-B in PP-PE Area.

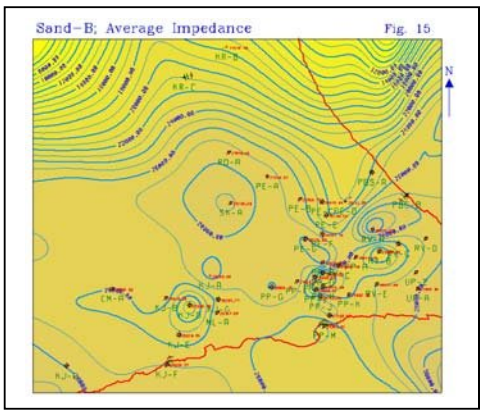

Figure 15: Average Impedance Map of Sand-B. Darker shades indicate higher values. Low values towards NW is due to shallow depth of burrial

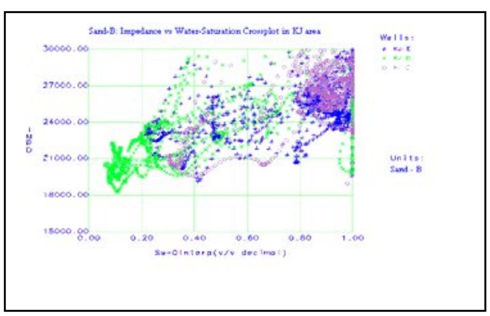

Figure16: Crossplot showing variation of impedance with water saturation of Sand-B. Gas section shows lower impedance.

Conclusions

This study has clearly brought out that

- Two main reservoirs Sand-A and Sand-B of Nannilam Formation are developed below and above the MFS respectively.
- Sand-A is aligned north-northwest to south-southeast along the present northern shore line. Sand-B in KJ-PP area aligning in east-west parallel to present southern shoreline.
- Both sands in PE area are deposited in channel setup. Porosity-thickness variation in this area gives a rough idea of the channel path. Average impedance of this sand is relatively high.
- For Sand-A better reservoir development is expected east of RV area i.e. towards PBS area may be probed for exploration.
- Sand-B in KJ area is much thicker & porous which reduces in thickness in PP area and subsequently pinches out further east. Better reservoir facies is observed at the crestal part of these fields.
- For Sand-B good quality reservoirs are expected in NNW of KJ area. Structurally favorable positions in these two areas of Ramnad sub-basin would be highly prospective.
- Analysis shows the contrast in impedance for gas & water bearing sections and adjacent shales except some overlaps. Sands in PE area are having relatively higher impedance than that in KJ-PP area.

Table:1 Impedance of gas and water sands

	Impedance in gm.ft/cc.sec	
Area	**gas zone**	**water zone**
Nannilam Sand-A		
Palk-bay-shallow	23000-28000	28000-32000
Ramanavalasai	21400-26000	26000-32000
Perungulam	24000-30000	26000-30000
Nannilam Sand-B		
Kanjirangudi	18000-26000	24000-28000
Periyapattinam	18000-28000	26000-30000
Perungulam	22000-30000	24000-30000

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Acknowledgments

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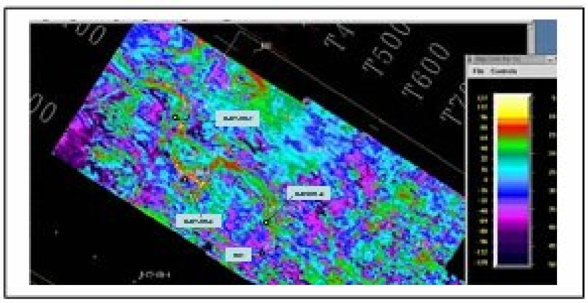
Appendix:

(i) Paleocene channel as reflected on seismic data.



(ii) Seismic correlation of wells KR-B; PBS-A & B;
RV-B & D