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Review of the Processing and Interpretation of Seismic data of C-24 field, Mumbai Offshore Basin- A case study

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Summary

C-24 field is being developed by drilling of 6 wells with peak gas rate @ 1.5 MMm³/d. Presently, four wells are on production producing about 1.2 MMm³/d. In view of additional accretion in the area from development drilling data and seismic data re-interpretation, the field is planned for additional/comprehensive development for exploitation of hydrocarbon.

The seismic data (OBC layout with parallel, End-on shooting) in the area was acquired in the year 1998-99 covering an area of 600 sq. km and was processed in the year 1999-2000.

The pay sands in the field occur in the depth range of 2300-2500m belonging to Daman and Mahuva formations of Oligocene age. The sands are deposited in the tide dominated deltaic regime as tidal sand bars and channels. The field has both structural and stratigraphically controlled hydrocarbon accumulations. Therefore, it was deemed necessary to review the Seismic processing and interpretation (PI) and the existing geological model to get a risk perception of the field.

The available geo-scientific data of the field were reviewed and OBC data was processed separately for hydrophone and geophone since the combined geophone and hydrophone data was found to be noisy and was making the sum data noisy and not amenable for attribute interpretation. Processing was also made to clean the geophone data and then summed (with hydrophone data) which shows better resolution than hydrophone data alone. The PSTM processed hydrophone as well as summed data were interpreted separately and attributes were studied for various pay zones and on comparison with the earlier post stack migrated seismic data reprocessed data were found to be of improved resolution. Pre-stack inversion attempted on the reprocessed data helped in fluid discrimination in the pay sands.

Introduction

The study area is around C-24 structure located in Tapti-Daman block of Western Offshore Basin. The pay sands in the field occur in the depth range of 2300-2500m belonging to Daman and Mahuva formations of Oligocene age. The sands are deposited in the tide dominated deltaic regime as tidal sand bars and channels. The pay sands are multi-layered with intervening shales and vary in thickness from 2 to 20m. The sands are fine to medium grained and are unconsolidated. The sands are fairly correlatable and show lateral variations in thickness. The field has mostly strati-structurally

controlled hydrocarbon accumulations entailing the review of Seismic PI and the existing geological model to get a risk perception of the field. The field is covered extensively with 2D and 3D seismic data.

Geological Setup of C-24 area

It falls in the Tapti-Daman block in the Western Offshore basin. Tapti Daman block is located in offshore Cambay Gulf area, which forms the northeastern part of Bombay Offshore Basin (Fig 1). The main feature of this block is the Surat Depression, which lies to the northeast of Bombay High platform and nearer to the mouth of Cambay Gulf.



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This depression is one of the principal source areas for hydrocarbon generation. Surat Depression remained a clastic basin during the entire Tertiary, while sporadic carbonate sedimentation has been observed in the south and the eastern part with shallowing basin configuration. The sandstone bodies have been deposited under tide dominated deltaic regime with gradual rise of sea level. The structural, stratigraphic as well as combination entrapment conditions are observed in the area for reservoirs of Daman and Mahuva formations of Oligocene age.

C-24 structure is located in the central part of the Surat depression. It is a north-south trending structural high with western bounding normal faults. The structure plunges gradually to the north. A number of longitudinal normal NW-SE trending faults traverse the western and eastern flanks of the structure. The western flank is relatively more faulted.

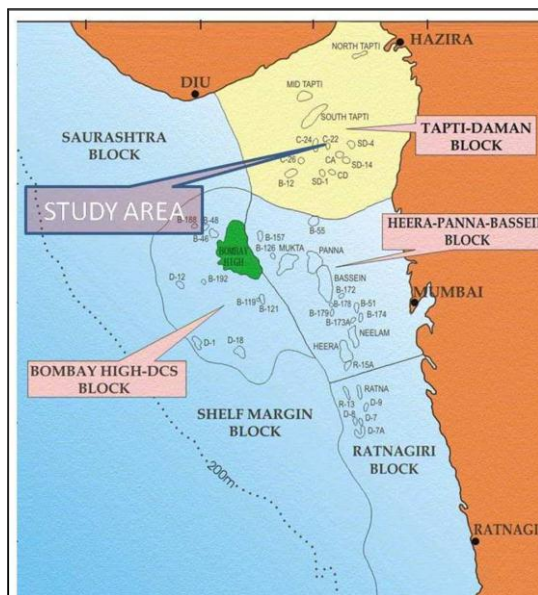


Fig.1 Map showing the area of study

Need for the study

The existing 3D seismic volume i.e. post stack migrated seismic data was interpreted and various attribute studies were carried out to predict pay sand thicknesses and their areal distribution in the field.

However, during drilling of the development wells, variation of pay sand thicknesses vis-à-vis the predicted thickness was observed. This observation led to skepticism about the estimate of the areal distribution of the reservoir sands derived from the seismic studies and thus it was felt necessary to review the seismic acquisition, processing and interpretation and the existing geological model to get a risk perception of the field.

Review of the existing Seismic Acquisition, Processing and Interpretation

Various aspects of the seismic PI and the existing geological model were reviewed. Two sets viz. Post stack time migrated and Pre-stack time migrated (PSTM) of data (Fig.2, 3) were available in the area. Out of these, Post stack time migrated data was used for amplitude based analysis and post stack inversion instead of PSTM data as the amplitude based studies carried out on the PSTM data were not very encouraging.

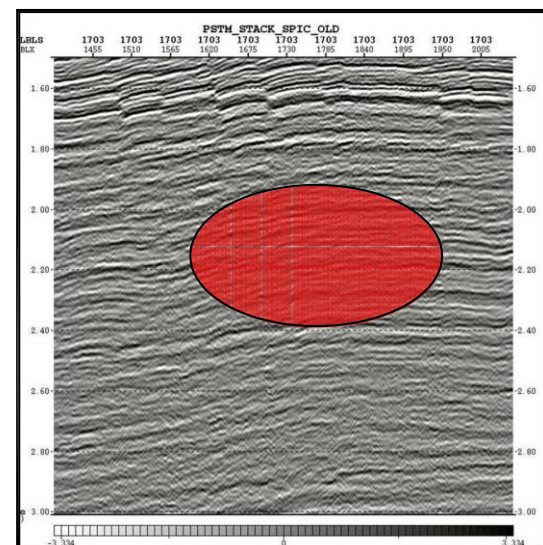


Fig.2 Inline from old PSTM data passing through well C-24B.

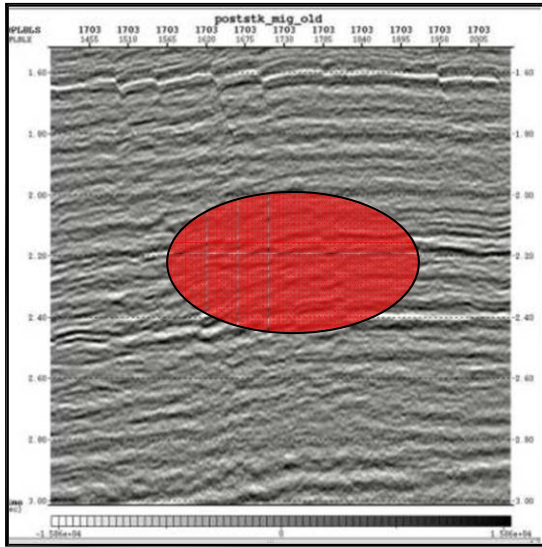


Fig.3 Inline from Post stack migrated data passing through well C-24B.

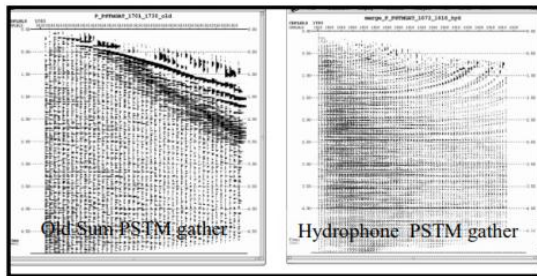
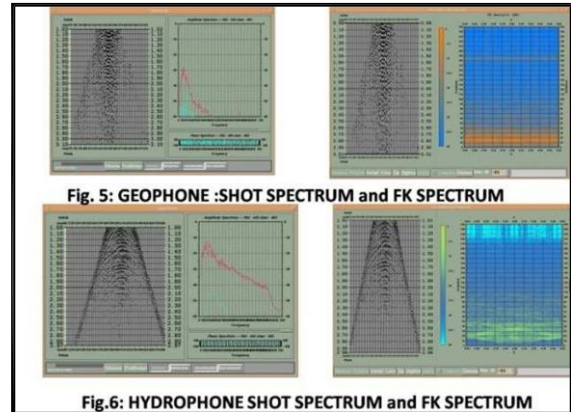


Fig.4 Comparison between old PSTM gather and hydrophone only PSTM gather from Pilot study at well C-24B.

Hydrophone alone gather was found to have better signal to noise ratio compared to old PSTM gather (Fig.4). Also, it was found that geophone data are of poor quality but the hydrophone data have high signal to noise ratio (Fig.5, 6). Poor geophone coupling in the soft mud at the sea floor is perhaps the reason for the poor quality of the geophone data. Geophone data are summed with hydrophone data (after spectral equalization) to attenuate sea-surface multiples. Here, the summation degraded the final quality rather than improving it.

Re-shooting the data was not perceived to be a good choice since it may be difficult to ensure good coupling of the geophone in this area. Hence, it was felt that hydrophone data be processed alone which was expected to yield better result than those obtained by hydrophone-geophone summation.



Post stack inversion inputs and outputs were reviewed. Due to poor quality stack, wavelet estimates obtained at available well locations were unrealistic. Only a composite wavelet derived from wavelets at 3 well locations was used in post stack inversion. Given the data, this was the best possible choice. Despite this, the results obtained are fairly reasonable and the results tie at the well location B-12-A very well (Fig.7).

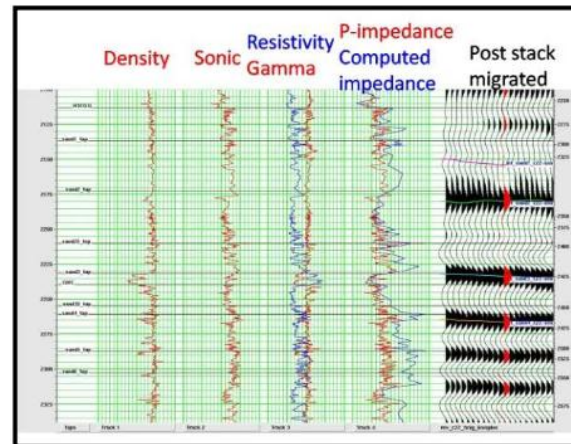


Fig.7 Inverted impedance trace superposed on the true impedance showing the quality of inversion achieved at B-12-A well.

Follow up action

A pilot area of around 35 sq. km.(Fig.8) was chosen from the prospect and the seismic data of the pilot area was taken up for re-processing. Hydrophone data alone was taken up for processing. The linear noise elimination and signal to noise ratio enhancement processes were applied on the raw data. It was found that hydrophone data showed



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considerable improvement over earlier summed data. (vintage-post stack volume) (Fig.9).

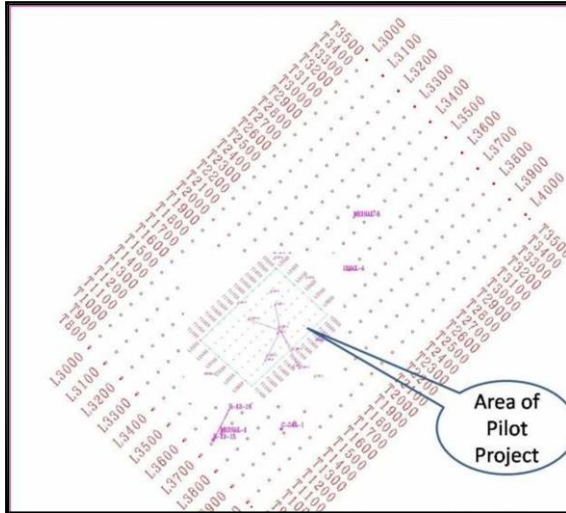


Fig.8 Base map of C-22/C-24 area

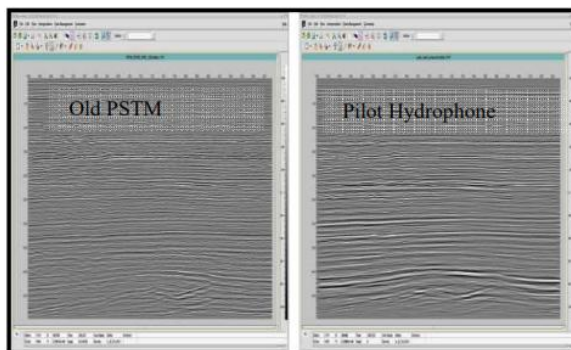


Fig.9 Stack sections from Old PSTM data and pilot project hydrophone data showing improvement in data quality.

Simultaneously, geophone data was also separately processed for noise elimination and stacked. Three stack volumes (Hydrophone alone, Geophone alone and Geophone+hydrophone together) were generated in the process and were available for analysis on a pilot basis (Fig.10).

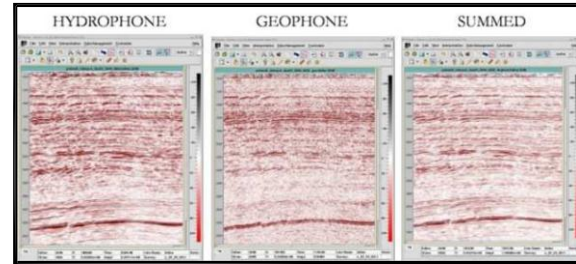


Fig.10 Pilot project processed data

Well to seismic tie and subsequently fresh horizon correlation was done in the entire pilot 3D seismic volumes. Also, the 3 volumes were zero-phased for subsequent analysis. In total, 6 volumes were available for the pilot study. There were 3 separate sand bodies viz. bottom, middle and upper to be investigated. The seismic horizons corresponding to these sands were correlated in all the volumes and attributes were extracted (Fig.11).

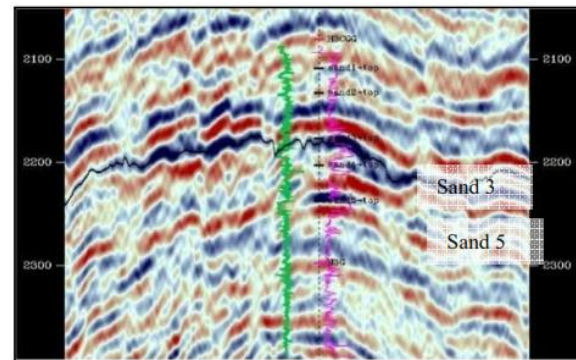


Fig.11 Inline from PSTM data with DAS (Hydrophone) passing through well C-24-A.

Results of the Pilot study

There was conspicuous improvement of the quality of seismic data compared to the previously processed seismic data. The seismic events have been clearly brought out in the reprocessed hydrophone and summed volumes.

The extracted seismic attributes were compared with the earlier extracted attributes. It was observed that geophone alone processed attributes didn't have a better spread and didn't yield better definition of the areal distribution pattern compared to the others i.e. hydrophone alone, and geophone and hydrophone both combined and also previously processed post stack migrated volume.



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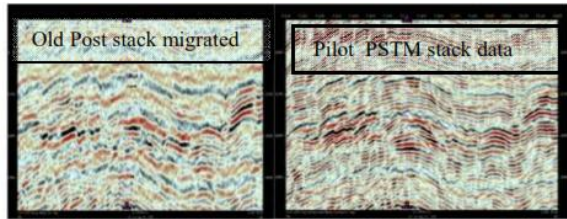


Fig.12 Comparison between Inline from Old Post stack data and new pilot processed PSTM data passing through well C-24-A.

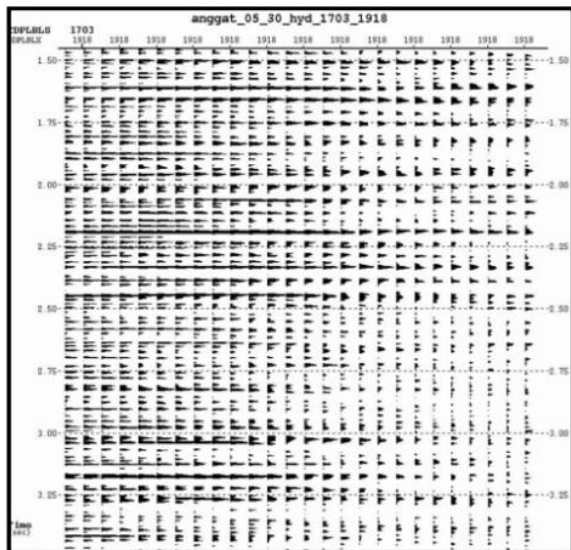


Fig.13 Pilot PSTM processed hydrophone angle gather at well C-24-B.

Overall, conspicuous improvement in the quality of the output of pilot project was observed (Fig.12). It was impossible to identify coherent reflections from sands in the pre-stack gathers in the old data set but in the pilot processed data set the quality has improved significantly. Improved signal to noise ratio and clearer identification of sands in the gathers are noticed. It is observed that though there was maximum offset of 6km, meaningful angles only up to 25 degrees could be generated (Fig.13). Post stack amplitude maps show some differences from old stack amplitudes, areas of some sands increased while those of others decreased (Fig.14a, b, c).

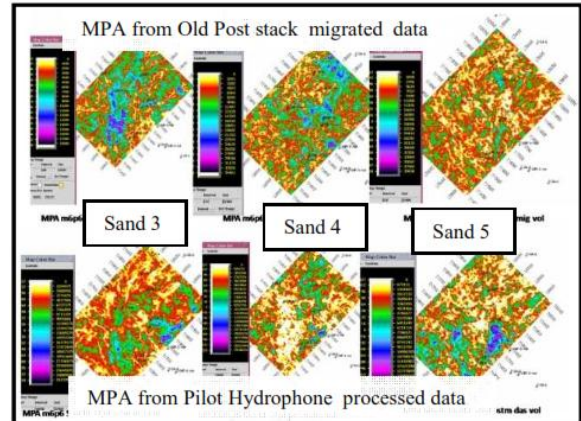


Fig.14a Maximum positive amplitude(MPA) derived from old post stack migrated volume and pilot hydrophone processed volumes over the sand 3, sand 4 and sand 5 intervals.

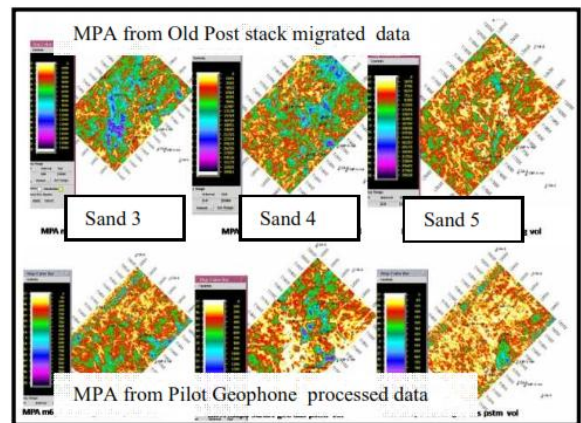


Fig. 14b Maximum positive amplitude(MPA) derived from old post stack migrated volume and pilot geophone processed volumes over the sand 3, sand 4 and sand 5 intervals.

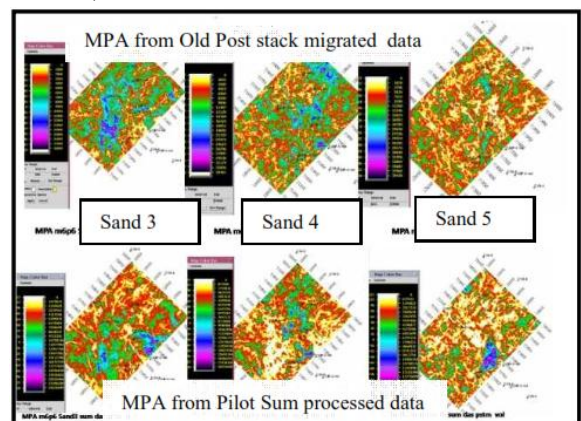


Fig. 14c Maximum positive amplitude(MPA) derived from old post stack migrated volume and pilot sum processed volumes over the sand 3, sand 4 and sand 5 intervals.



Well Logs

There are 6 (six) Exploratory wells and 4 (four) development wells in the pilot area. Out of these wells, 2 have shear logs and only 2 wells have both sonic and density logs. Rest of exploratory wells have either a sonic log or density log.

It is observed that well logs show clear discrimination between gas sand and water sand in the Vp-Density cross plot and AI-Vp/Vs ratio cross plot (Fig 15a,b).

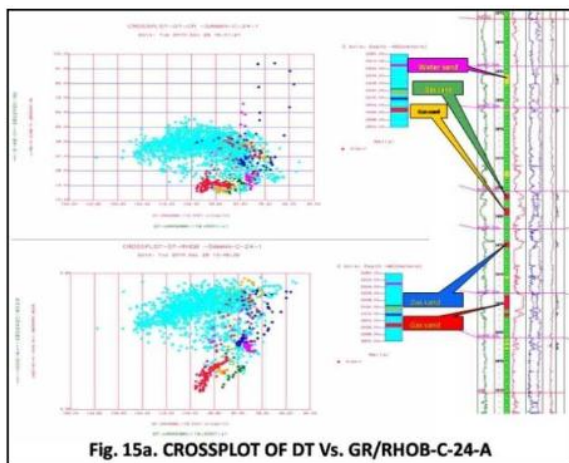


Fig. 15a. CROSSPLOT OF DT Vs. GR/RHOB-C-24-A

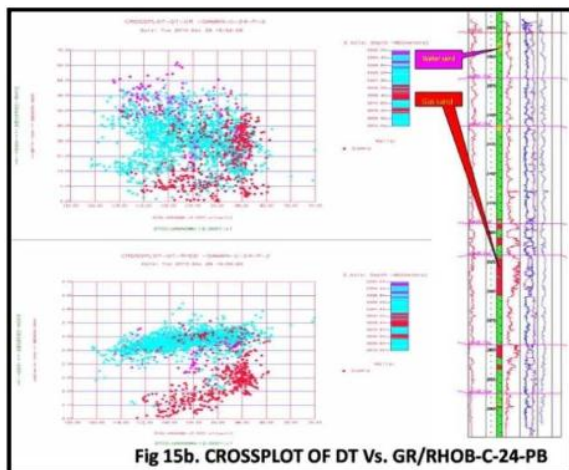


Fig 15b. CROSSPLOT OF DT Vs. GR/RHOB-C-24-PB

Since post stack inversion estimated only acoustic impedance and pre-stack inversion estimates both acoustic impedance and Vp/Vs ratio which is essential for discrimination of hydrocarbon bearing reservoir from the

brine sands, it was deemed essential to carry out pre-stack inversion of the reprocessed seismic volumes of the pilot project.

Pre-stack inversion

The figures Fig.15c and 15d pertaining to the well C-24- PB show cross plots between Vp/Vs ratio and the acoustic impedance. A clear separation of gas sand for low Vp/Vs ratio and low acoustic impedance is noticed. The primary goal of attempting the pre-stack inversion in this pilot project was to see if we could map zones of low Vp/Vs ratio and low acoustic impedance in the entire volume.

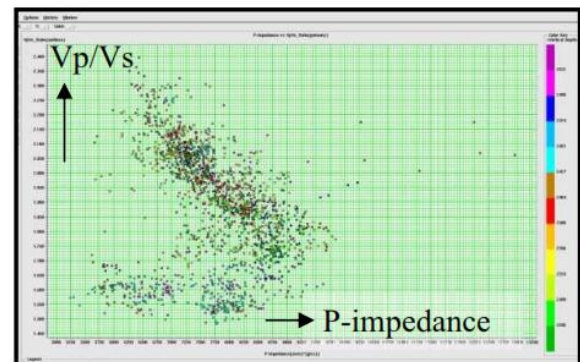


Fig.15c Crossplot of Vp/Vs ratio vs Acoustic impedance at well C-24-PB.

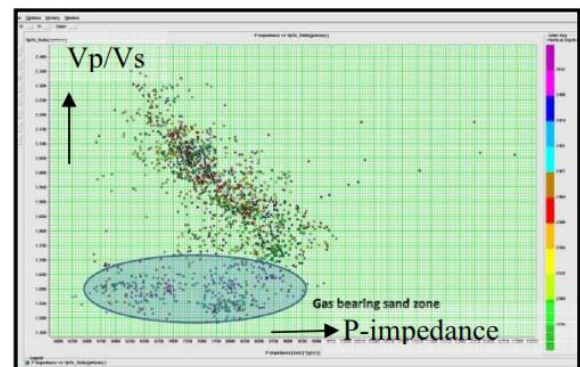


Fig.15d Cross plot of Vp/Vs ratio vs Acoustic impedance from well C-24-PB showing separation of gas bearing zone.

Following 3 scenarios were tested

- Broadband well log starting model: Strong bias to wells
- 20-25Hz well log starting model: moderate bias to wells



- 10-15Hz well logs starting model: Soft bias on well logs

The Fig. 16 is a cross plot of Vp/Vs versus AI from pseudo logs derived from pre-stack seismic inversion. We observe that seismic inversion is able to provide some indicators of gas zones as observed in the true log i.e. zone of low Vp/Vs and low acoustic impedance.

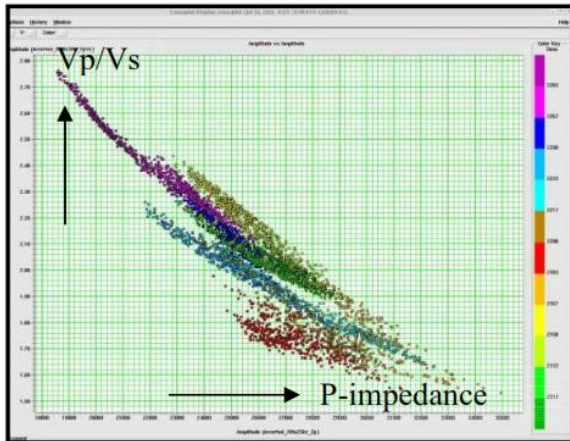


Fig.16 Cross plot of Vp/Vs ratio vs Acoustic Impedance from seismic pseudo logs

Zonation

We classified zones in the cross plot (Fig.17) and translated them into the seismic section (Fig.18a, b) without taking any bias to which sand interval it was being referred to. Thus the entire Daman pack was considered for the analysis. On transferring the zone to the seismic section, it was found that the red zone(zone of low Vp/Vs and low acoustic impedance) corresponds to the gas bearing interval in the Daman reservoir.

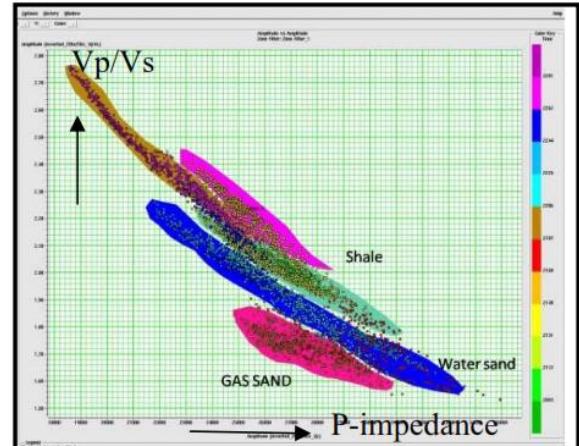


Fig.17 Zonation and lithology interpretation in Crossplot of Vp/Vs pseudo-logs v/s Acoustic Impedance pseudo logs

Interestingly, the development well C-24-PB(Fig. 18a) which was kept out of the calibration/inversion process also has been corroborated in the process to be hydrocarbon bearing. The hydrocarbon bearing interval in the well is verified by the transference of the zone onto the seismic section which match well with the occurrence of the hydrocarbon in the well. This validates the effectiveness of the pre stack inversion of the reprocessed data of the pilot area.

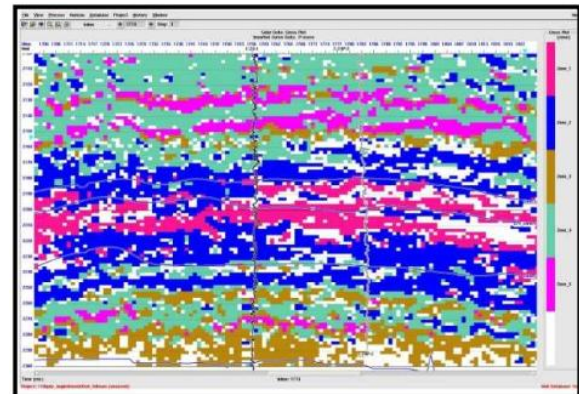


Fig.18a Indicative lithology and fluid zonation in Daman formation projected from cross plot of pseudo logs shown in Fig.17.

RMS amplitude values over the Sand 3 interval were derived from the Vp/Vs volume generated from the pre-stack inversion of seismic data over the Pilot area and studied with reference to the hydrocarbon occurrence.

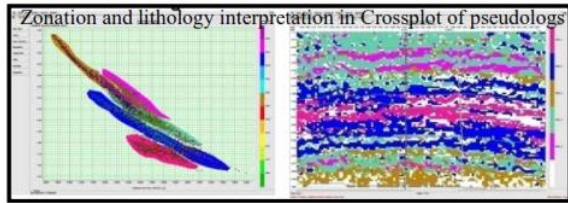


Fig.18b Transfer of Zones identified in Cross plot of Vp/Vs ratio v/s Acoustic impedance onto the Seismic Section.

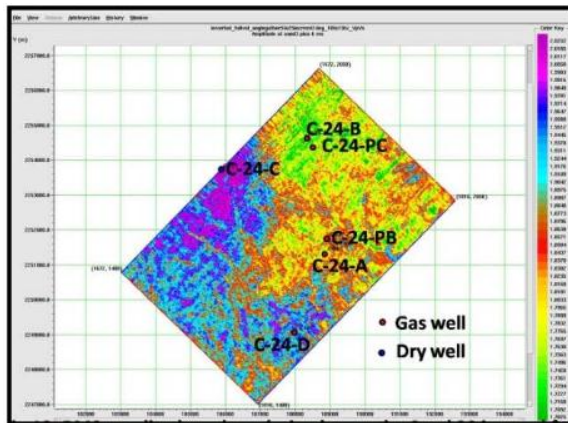


Fig.19 RMS amplitude derived over the sand 3 interval from the pseudo Vp/Vs volume obtained from pre-stack inversion.

It was observed that gas occurrence is predominantly in the northeastern part of the area near the well C-24-B (Fig.19). It is corroborated by the drilling results of the development wells in the vicinity of C-24-B well.

Observations

- Results from seismic inversion are highly encouraging.
- In the absence of shear logs mud rock equation and FRM transforms were used to generate the shear logs in the pre-stack inversion. It will be better if Shear logs are recorded in the wells.
- Despite the offset of around 6kms in the offset gather, meaningful angle range could be generated only up to 25 degrees. If angle range can be increased further, it will yield better pre-stack inversion results.

Conclusion

- In the OBC data of C-24 field, geophone data was found to be of poor signal to noise ratio compared to the hydrophone data. Therefore, hydrophone data of the area may be processed separately and used for subsequent interpretation.
- The pay sands in the area are characterized by low Vp/Vs ratio and low acoustic impedance. They stand out as separate clusters in the cross plot of Vp/Vs ratio v/s Acoustic impedance. Pre stack inversion of the 3D seismic data in the area may be carried out to obtain Vp/Vs, Acoustic impedance, Shear impedance and Density volumes and fluid discrimination in the reservoir may be attempted for the field.

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Reference Manual of Hampsson-Russel Software for
Acoustic and Elastic inversion.

(The views expressed in the paper are those of the
authors only and not of ONGC).