RESERVOIR CHARACTERISATION OF BASAL CLASTICS AND OVERLAYING PANNA SEQUENCE IN BASSEIN FIELD USING IMAGE LOGS

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ABSTRACT

The Basal Clastics and the over laying Panna sequence in Bassein Area of Western offshore, India are complex units both depositionally and lithologically. The depositional complexity ranges from sand – shale alteration with sands varying between conglomerates, fine grained to coarse grained with intervening occurrence of coal layers. Added to this is the presence of heavy conductive minerals which effects the density log severely and also the resistivity log to a large extent. The combined effect of all these complexities results in unconventional log responses except the places where there are clean sands. In order to characterize the reservoir realistically an attempt has been made to integrate the Formation Micro Imager (FMI) Images with the conventional resistivity and porosity logs during evaluation. The thin laminated sequences which are beyond the resolution of conventional tool emerge out conspicuously on the image logs. The production testing data of many of the wells where very good productivity is seen shows poor response on conventional logs. However, three wells where FMI log is available shows thin laminated sand-shale sequence against such zones. An estimate has been made to determine the sand count in such laminated sequences, where the effective sand thickness increases substantially compared to the conventional analysis. The possible good productivity in testing in such reservoirs could be due to larger sand thickness as deciphered by FMI.

INTRODUCTION

The Bassein field is located in the continental shelf of Arabian Sea about 80 km west of Mumbai city Fig.1. It is a N-S trending elongated asymmetrical anticline with an aerial extent of about 200 sq. km and vertical closure of about 120 m. The eastern limit of the structure is faulted with down throw towards east. The western limb is having gentle slope where as the eastern one is steep. So far, the main focus has been Bassein Formation from the Eocene age and this has been the largest Gas producing field of India since 1988. Bassein Formation is overlain by Mukta Limestone formation from Oligocene age and underlain by Panna Clastic sequence from Paleocene age. Mukta is a tight limestone sequence with minor porosity development. The Production from Mukta Formation is from very few wells due to its poor reservoir quality compared to Bassein Formation. The hydrocarbon potential of Panna formation was tested in some of the exploratory wells (spanning from A-5 in the west and Z in the east) and reserves were accreted.
The reservoir character from standard log evaluation shows very poor reservoir character in wells such as Y (Fig.2) and X (Fig.3)
comparatively thin clean sandstone reservoirs are present. However, the testing results of these wells indicate even the poorest of the reservoirs have good flow potentials, which otherwise gets masked through conventional log interpretation. Complimenting to this, the recent production data shows a promising performance. 

Fig. 3

Fig. 4
performance from a thin sand interval of Panna in B-1 well for the past two years @1600 bopd drew the attention for a comprehensive understanding and development of this reservoir.

**SEISMIC STUDY**

The well log impedance response of Panna formation clearly brings out three ranges of values viz., high impedance for the shale below Panna top, low impedance for the coal beneath the shale and medium range of impedance for the reservoir sands that are stacked below the first regional coal. This stack is interlaced with thin streaks of shales, silts and coals. The top of the basement is characterized by high impedance.

The case for wells A-5 and C-1 the general log impedance character grossly appear similar with less of coal streaks in the reservoir stack, while for B-1, A-4 the number of coal streaks are more. BE-2 the sands are not good or the reservoir is more of silty in nature. Almost similar range of log impedances have been observed for the wells in the Eastern part viz., Z.

To address the reservoir layer properties and their spatial distribution, post stack model based seismic inversion has been carried out. This addresses the layer thickness issues as well as its reservoir quality/property spatially. To bring out the sand extensions in the A-3,B-1 ,C-1 and A-2 blocks,a window is considered from the base of the first coal (TC) and down to sand3. The clear spread of the medium range of impedances in A-3 block,B-1 block for the upper window indicate potential area to the west of A-3 well (Fig.5).
The C-1 and A-2 corridor came up well with larger spread around A-2 well. Also, the extensions are seen in the southeast part of A-1 well. The picture near A-5 well has also come up very well and is in line with the spectral decomposition result (Fig6).

FMI INTERPRETATION

The Seismic studies through impedance, inversion and spectral decomposition analysis indicate areas with good facies development. This will further strengthen our efforts to delineate the formation through exploratory drilling at the prospective areas within the field. However, the available conventional log data against already drilled wells indicate wide variation in their facies. Contradictory to this the very good testing results against many of the wells with apparent poor reservoir character as seen by conventional log has prompted to look in to the reservoirs using the high resolution FMI logs. The available FMI data in wells A-2, A-3 and A-5 (Fig7) have been interpreted to carry out fine scale characterization of the Panna Sequence.
The Panna sequence lies conformably over the granitic/basaltic basement in the Bassein area. This sequence consists of the main Panna-Coal shale section followed by the marine shale sequence over which lies the lower Bassein Limestone (Fig-8).

Towards the western flank of Bassein field lies well D-1. The FMI interpretation of this well clearly shows the absence of Basal clastics with the basement directly underlying the Panna Coal-Shale sequence (Fig-9 and Fig-10).
The presence of large number of high angle fractures in the top part of the basement (Fig. 11 & Fig. 12) renders it to be an interesting exploration target.
The abundant presence of vugular porosities in the basal clastics (Fig. 13) also brings out the good reservoir nature of this unit worthy of being an exploration objective.

**PANNA SECTION**

The hydrocarbon potential of the Panna formation is limited to the main Sand-Coal-Shale sequence. This sequence consists of mainly sand, shale, coal with occasional limestone streaks interspersed with tight layers and conglomeratic beds (Fig. 14).
The hydrocarbon bearing layers have been divided into three sand units viz. sand units 1, 2 and 3 from top to bottom on the basis of the coal markers. The conventional log interpretation with density-neutron separation as sand-shale indicator had initially shown sand presence in a limited way. However, the testing of various wells in Panna section had shown good production against zones with apparent extremely shaly situation from standard logs. The estimated reservoir properties against these shaly zones had been inferior with low porosities, low hydrocarbon saturation and lower effective thickness.

The analysis of FMI image data in the above three wells brings out a different picture of the Panna section other than the conventional logging tools. The Panna section appears to be highly laminated with varying thickness of shale/ sand and coal. Laminations as thin as 20-30 cms which are clearly beyond the resolution of conventional tools seems to be dominant in the sequence (Fig. 15).

The good productivity of some of the wells against highly shaly zones interpreted using neutron-density and GR logs could be due to these laminated thin sands. 

**LIKELY INCREASE IN PAY THICKNESS DUE TO THIN SANDS**

The thin sands observed in FMI image have remained conspicuously absent in the pay estimation from conventional logs. An attempt has been made to pick all the sands from FMI image and compare this with the sand thickness obtained from conventional logs. This analysis in well: A-3 shows a substantial increase in pay thickness (Conventional pay thickness: 3 m and FMI based pay thickness : 8.5 m) as shown in Figs. 16 to Figs 18.
Effective sand thickness = 3.75 mts (layers more than 50 cm thick)
For Interval : 2120 -2134 mts

Effective sand thickness = 4.75 mts (layers more than 50 cm thick)
CONCLUSIONS

- A comprehensive study and analysis of various seismic attributes, spectral decomposition and inversion indicated areas of good sand development in areas around A-5, C-1 and B-1.
- The presence of fractures in the Basement section provides an interesting lead in terms of Basement exploration in the updip section of Bassein Field for possible hydrocarbon accumulation.
- The limitation of conventional tools in identifying the thin hydrocarbon sands have been addressed by the use of high resolution FMI image data. The additional pay thickness coming out from such thin layers could answer the good productivity during production testing and subsequent consistent production in wells like BC-9 within the Panna section.
- The production testing result of A-2 (Qo=1828 bbls/d, Qg=65445 m3/d, GOR=224 v/v, bean=1/2”), indicates the producing sand to be highly permeable. The laminated sands seen on the FMI image have to be very productive to account for such production.
- In addition to the issue of productivity, this enhanced pay thickness could substantially accrete additional reserves in the Panna formation.

RECOMMENDATIONS

- Future work for Panna formation need to be carried out at pre stack level that is simultaneous inversion studies and computation of S wave impedance, poisson’s ratio for ascertaining the precise sand delineation.
- The FMI interpretation has brought out the complex nature of the Panna Sequence. To carry out better reservoir characterization through detail mineralogical and petrophysical studies, conventional core should be taken in Panna section in the future wells.
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