Application of Reflection Amplitude for Delineation of Thin Reservoir

Gyanesh Chandra, Harjinder Singh, A.K. Jena & RamAvtar
Ahmedabad Assett, ONGC, Ahmedabad

ABSTRACT: The Cambay basin is an intracratonic rift graben and came into existence at the close of Mesozoic period. This Basin is sub divided in several blocks by a set of transverse faults. The Ahmedabad –Mehsana block is the one of the block of Cambay Basin where area of study, Nardipur, is situated. Several pay horizons are present in the area in Kalol formation. Kalol-VA is the most prolific producer pay horizon in the area. Pay horizon Kalol-VA is overlain and underlain by coal beds, the thickness of the pay sand is very less (<\lambda/4 ). The attribute studies could not give any significant lead due to inherent limitations associated with data acquisition and processing. Therefore to avoid such limitations which impair reflection amplitude, the ratio of reflection amplitude of pay horizon with a reference horizon has been studied to apply the concept for delineation of sand in the area. In the 3D area better thickness of sand development has been identified and entire area is divided in to two parts one where good thickness of sand is expected and other area where poor thickness is expected. The inferred sand development trend follow same trend as shown by already drilled wells. The ratio method is especially applicable in offshore where a good reference reflector, a sea bottom reflector, is present in the entire area.

INTRODUCTION

Nardipur area is situated in Cambay basin of Gujarat state(India). The nardipur area has been mapped by gravity, magnetic and 2D seismic surveys. The area has been recently covered by 3D seismic survey under SIG-368. Nardipur is located near Kalol field which is a multilayered reservoir in Kalol formation (Plate-1).

The reservoir sands (Kalol-V and IX sands) in area are very thin (max thickness 8mts.) and generally overlain and underlain by coal beds. The Kalol-VA is the main producer in the area. It is observed from the well data that the increase in thickness of unit is solely due to sand development. The Kalol-VA is not sufficiently thick to give rise to independent reflections from the top & bottom of the sand. In general the thickness is less than \lambda/4 . To delineate such a thin sand the amplitude of reflection can be studied that will be an estimate of the thickness.

GEOLOGY OF THE AREA

The generalized stratigraphy succession for this area is given below:

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle Miocene to Recent</td>
<td>Post Kand</td>
<td>0-615</td>
</tr>
<tr>
<td>Lower to Middle Miocene</td>
<td>Kand</td>
<td>615-830</td>
</tr>
<tr>
<td>Lower Miocene</td>
<td>Babaguru</td>
<td>830-1070</td>
</tr>
<tr>
<td>Upper Eocene to Oligocene</td>
<td>Tarapur</td>
<td>1070-1315</td>
</tr>
<tr>
<td>Middle to Upper Eocene</td>
<td>Kalol</td>
<td>1315-1600</td>
</tr>
<tr>
<td>Lower Eocene</td>
<td>Cambay Shale</td>
<td>1600+</td>
</tr>
<tr>
<td>Paleocene</td>
<td>Olpad</td>
<td></td>
</tr>
</tbody>
</table>

Hydrocarbon traps in Wavel Member (Kalol-II,III,IV & V) are stratistructural and in Sertha Member (Kalol-VI, VII, IX & X) are independent of structure.

The Kalol-VA is the main reservoir in the area. In general the average production is @40m³/day. The production
and reservoir behaviour show that the reservoir is extensive. The Kalol-V unit in this area is subdivided into VA and VB by a well correlatable coal (Plate-2, 3). The maximum thickness of sand is around 8mt and the sand is overlain by a thin shale unit of constant thickness of around 5mt in the area.

**CALIBRATION & SEISMIC STUDIES**

Several sands in the Kalol Formation are producing in the area. These sands are separated by shale and coal units. The precise identification and correlation of reflector corresponding to Kalol-VA, Kalol-IX & Kalol-X is most essential for delineation of paysand. Several synthetic seismograms of nearby wells and wells falling in the area were prepared using the sonic and density logs. The synthetic seismograms prepared with optimal wavelet enables a good time fit with the seismic section (Plate-4). The synthetic seismograms match with seismic section, all horizons e.g. Kalol-VA, Kalol-IX & Kalol-X were identified on the seismic section. The seismic events corresponding to Kalol-VA and Kalol-IX horizons were tracked in the 3D volume (Plate-5) after calibrating the relevant reflector through synthetic seismogram. The interpreted in line seismic section A-6 and B-00 are shown in Plates 6 and 7. The time structure maps at
Kalol-VA and Kalol-IX top were prepared for the study of structural disposition and fault alignment in the area (Plate 8, 9). The seismic attribute e.g. phase, instantaneous frequency and reflection strength were studied for the horizon corresponding to Kalol-VA horizon (Plates-10, 11, 12). All the attributes in general could not yield any significant trend that can lead to delineation of sand. Here it is noteworthy that seismic attributes specially reflection amplitude gets effected by several factors arising during acquisition like ground coupling, instrument sensitivity and variation in stack fold.
Application of Reflection Amplitude

The reservoir under study are thin (<λ/4) so the thickness effect on amplitude should also be considered. Widess gave formula relating reflection amplitude to the thickness of the reflector.

Plate 10

Plate 11

Plate 12

METHODOLOGY

The reservoir under study are thin (<λ/4) so the thickness effect on amplitude should also be considered. Widess gave formula relating reflection amplitude to the thickness of the reflector.

Suppose the impedance of reflector unit b be \( r_2 \) and it is overlain by stratigraphic unit of impedance \( r_1 \) and underlain by a unit c of impedance \( r_3 \), the reflection amplitude from the interface of unit a and b be \( S_{01} \) and the reflection from the interface of unit b & c be \( S_{02} \).
Application of Reflection Amplitude

The ratio of amplitude \( S_{02} \) and \( S_{01} \) from the top and bottom of a reservoir may be given where all unit are thick

\[
\frac{S_{02}}{S_{01}} = \frac{4r_1r_2(r_3 - r_2)}{(r_2^2 - r_1^2)(r_3 + r_2)}
\]

(1)

If a reflector is thin \((< \lambda/4)\) then amplitude

\[
S = \frac{4\pi}{\lambda} S_0 t
\]

(2)

where \( S_0 \) is the reflection amplitude from thick reflector and t is the thickness of the reflector.

Let unit b thickness is \( t_1 \) and unit c thickness is \( t_2 \). Using equation (1) and (2) the relation for the amplitude ratio from thin beds can be found out.

\[
\frac{S_2}{S_1} = \frac{4r_1r_2(r_3 - r_2)}{(r_2^2 - r_1^2)(r_3 + r_2)} \frac{\lambda_1 t_2}{\lambda_2 t_1}
\]

(3)

Where \( S_2 \) and \( S_1 \) are amplitudes when thicknesses are small. The estimation of the amplitude ratio can be made from the well logs namely sonic and density using equation (3). Replacing unit b in fig-1 by Kalol-IX coal unit and unit c by Kalol-VA unit then equation (3) can be used for the estimate of amplitude ratio at certain point using the well data since all variables of right side of equation(3) are known.

From the producing well data falling in the area \( r_1, r_2 \) and \( r_3 \) were calculated from density and sonic log. Prevalent frequency in the data is 30Hz, putting all value from well producing from K-VA equation (3) reduces to

\[
\frac{S_2}{S_1} = k \frac{t_2}{t_1}
\]

(4)

Where k is constant

The coal thickness is not increasing rapidly, in \( 3/4 \) th of the area it is nearly constant \((11-13 mts.)\) afterwards it increases towards east of the area of the study. At the location of producing well from Kalol-VA, the optimum value of ratio is calculated using equation (4) and that was kept as the representative value exhibiting development of sand thickness similar to the test well. High value ratio show a thicker sand development whereas less ratio show thinner sand development. The colour scheme is selected in such a way that yellow colour show area corresponding to ratio \( \geq 1 \) and blue colour shows the ratio \( < 1 \). The amplitude ratio map shows a trend of sand development represented by a yellow colour and recently drilled wells falling in this trend shows good development of Kalol-VA sand thickness whereas several wells falling in blue area are showing poor development of Kalol-VA sand. With this concept prospective areas has been identified within 3D Nardipur area. The major sand development follow the same trend as shown by drilled wells falling South of area of study.

CONCLUSION

The delineation of thin pay sand can be achieved through seismic attribute study. This method of amplitude ratio is more useful in area where a good reference reflector is present for e.g. in offshore area where water bottom give a strong reflector and it can be used as a reference reflector, other geological marker present in the area may also be taken as a reference reflector and delineation of thin sand can be performed.
ACKNOWLEDGEMENTS

The authors acknowledge the infra-structural facilities provided by Oil and Natural Gas Corporation Limited, India in carrying out this study. Authors acknowledge their sincere thanks to Shri Lehmbar singh, E.D.-Asset Manager, Ahmedabad Asset for his continuance encouragement, guidance and keen interest shown in the work. Authors also express their sincere thanks to the Head, IRS for providing the infra-structural facilities for conducting the studies.

Thanks are also due to Shri M.S.Rana, D.G.M (Geology), Shri P.K.Gupta, C.G. and Surendra kumar S.G. for valuable suggestions during the preparation of this paper. Authors are thankful to the help rendered by Shri Munishwar Singh D.G.M (W) in the preparation of the plates of this paper.

REFERENCES

Widess M.B(1973) How thin is a thin bed? Geophysics 38 pp 1176-1180
Anstey, N.A (1977) Seismic Interpretation, IHRDC, Boston Mass.USA
Boyer, S etal (1977) Seismic Surveying and well logging , Oil and exploration Technique Paris.
Brown A.R. (1986 ) Interpretation of three dimensional seismic data ,AAPG, Memoir :42 , Tulsa Oklahama, USA