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# Detection of Thin Sand by Using Seismic Inversion in Gandhar field of Cambay Basin, India-A Case Study

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***Summary***

*Deltaic sands of Hazad formation of Mid-Eocene age are hydrocarbon bearing in Gandhar field of Cambay basin. Greater depth of burial, lesser thickness of reservoir sands and encompassing shale as compared to wavelet duration, their discrete nature of occurrence make precise mapping of individual pay sands a challenging task despite sands having higher impedance than shale. The challenge has been met in delineating the GS-1 sand; the bottommost of 12 sands in Hazad unit by utilizing the fact that the thin sand overlies the shale and its base is easily correlatable on inverted seismic volume. Other observation utilised for the mapping has been that the lower part of GS-1 sand is tight and fine grained resulting in higher average impedance despite the producing upper part of the sand which is highly porous and clean having low impedance comparable with shale. Impedance log of all the wells filtered at seismic band shows the complete sand unit as high impedance confirming the fact that high impedance characterizes the reservoir facies, whereas the low impedance corresponds to poor/shale-dominated reservoir. This led to the inversion of 3D seismic data for mapping acoustic impedance over GS- 1 interval. GS-1 top has been constructed over the area mathematically using the correlated base of the sand and two way time thickness of GS-1 sand unit observed at well locations. The sand distribution mapped by calculating mean impedance over the GS-1 interval is validated by all the wells in the area. The facies map explains sand distribution encountered in the wells and also shows additional area available for delineation.*

***Keywords****: Thin sand detection, inversion, acoustic impedance.*

## Introduction

Gandhar field is one of the major fields in Jambusar-Broach block of Cambay basin, India. The field was discovered in 1983 and put on production in 1984. Oil and gas have been produced mainly from different sands in Hazad member of Ankleshwar formation stacked one over the other with intervening shale units. Interpreted to be structurally controlled, the main pay sands are the hydrocarbon producers from more than six hundred wells. GS-1 pay sand has been developed in the eastern and other part of the field and it is producing from 3 wells in the eastern part. These sands are occurring at a depth of about 3000m and the thickness varies from 3 to 5m. Larger depth and lesser thickness, apart from discrete nature of deposition of these sands, make the imaging and precise mapping from seismic data very difficult. The present work describes a methodology to map GS-1 pay sands with a view to identify additional area for exploration.

## General Geology and Stratigraphy

Cambay basin is an intra-cratonic basin, developed along the Western boundary of central India. The basin is bounded by the Aravalli range and Deccan craton towards east and Saurashtra craton towards west. The study area is shown in Figure 1.

Sedimentation in Cambay basin started during Mesozoic period when it was genetically related to Kutch and Saurashtra basins. During Cretaceous age the entire basin was covered by extensive lava flow, known as Deccan Trap, blanketing the earlier deposited Mesozoic sediments. Like in other parts of Cambay basin Deccan Trap acted as the basement for deposition of a huge thickness of Tertiary-Quaternary sediments. Generalised Stratigraphy of Jambusar-Broach block, Cambay basin is shown in Figure2. Deccan Trap is unconformably overlain

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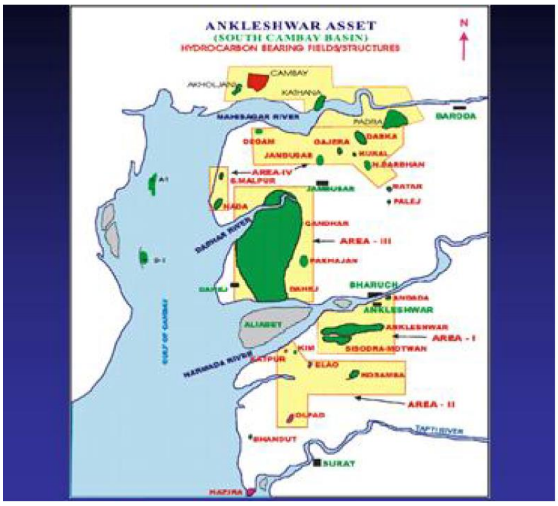

Figure 1: Prospect map of Cambay Basin showing study area.

by Olpad Formation of Paleocene age comprising Trap conglomerates, poorly sorted sands and claystone. Olpad Formation is unconformably overlain by thick monotonous Cambay shale of Lower to Mid-Eocene age. Ankleshwar Formation of Mid to Late Eocene age overlies the Cambay shale. It consists of two arenaceous members, viz., Hazad and Ardol, separated by Kanwa Shale Member. The Hazad Member of Ankleshwar Formation has been a prolific producer of hydrocarbon in this basin and the present study is an attempt to characterise the reservoir sand within this Member. The younger Ardol Member is overlain by Telwa Shale Member. Ankleshwar Formation is overlain by Arenaceous Dadhar Formation of Oligocene age, which in turn is overlain by post Dadhar Formation of Miocene to Recent age.

| AGE | THICK (m) | Lithology | Formation: Lithological Description |
|---|---|---|---|
| Recent | 50-100 | | GUJ. ALLUVIUM: Yellow & Grey Clays |
| Pliestocene | 400 | | JAMBUSAR: Clays, Sands, Gravel |
| Pliocene | 300 | | BROACH: Brown Clay St.,SST |
| Miocene | 200<br>200<br>300 | | JHAGADIA: White & Grey Cal SST., Shaly SST<br>KAND: Grey Clay, Clay ST.,Conglomerate<br>BABAGURU:SST., Grey Clays, Clay ST. |
| L.Mio-E.Olig | 150 | | TARAKESVAR: Variagated Clay ST., SST.,Carb. Shale |
| E.Olig-U.Eoc | 250 | | DADHAR:Grey Shales, Arg. SST.,Coals, SST |
| M.Eoc-L.Eoc | 500 | | Telwa: Shale with SST, Ardol: SST.,Shale,<br>ANKLESVAR: Kanwa: Shale, Silt St. Hazad: SST. |
| L.Eoc-M.Pal | 430 | | CAMBAY SHALES: Shales |
| M.Pal- L.Pal | 250 | | OLPAD: Shale, Silt ST. , Trap Derivatives |

Figure 2: Generalized Lithostratigraphy of Jambusar-Broach block, Cambay basin .

## Study Area

The area under study lies in the eastern part of the central Block of Gandhar field, Cambay Basin, India. GS-1 sand of Hazad member of Ankleshwar formation belonging to Middle Eocene age is the main producer in this block. This is the first extensively deposited sand of Hazad member. It overlies thick transgressive Cambay shale and is separated from the younger sands by a thin continuous shale unit deposited as a result of short period of transgression. The sand is well correlatable on electrologs and the log motifs suggest that the sand has been deposited in deltaic environment. Hydrocarbon has been established in this sand in central and southern blocks of Gandhar Field with large gas cap. In addition to the main block the oil block towards the east is also producing from this sand. Oil production commenced from GS-1 sand in May 1994 from well D which is structurally higher. A total of 16 wells i.e. A-P have been completed in this block (Figure 3). Currently, three wells viz. L, M and N are producing oil @90m 3/d with 2% of water cut. In this area, structure is not solely playing the role in hydrocarbon entrapment; rather presence of reservoir facies seems to hold more significance. Seismic inversion study was carried out to identify the GS-1 reservoir facies. On the basis of this study, GS-1 reservoir sand has been identified in eastern and northern part of the estimated area.

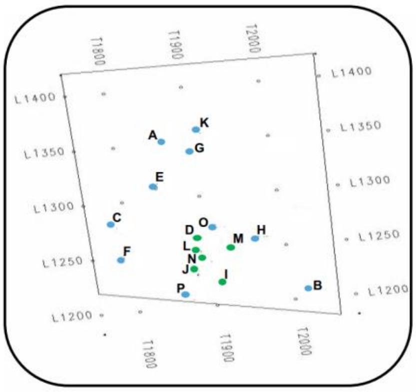

Figure 3: Location Map of the study area.

## Seismic study and analysis

3D seismic interpretation was carried out on the eastern part of merged PSTM data acquired in different phases with a bin size of 40mx20m; 32 bit with sampling interval of 2 ms. The quality of data shows fair resolution in the seismic band width. The general data quality of the 3D data volume with in the Hazad unit is fair. Seismic events corresponding to Hazad Top & Base were correlated on the basis of synthethic seismograms prepared for D, G, B, I etc.( Figure 4).

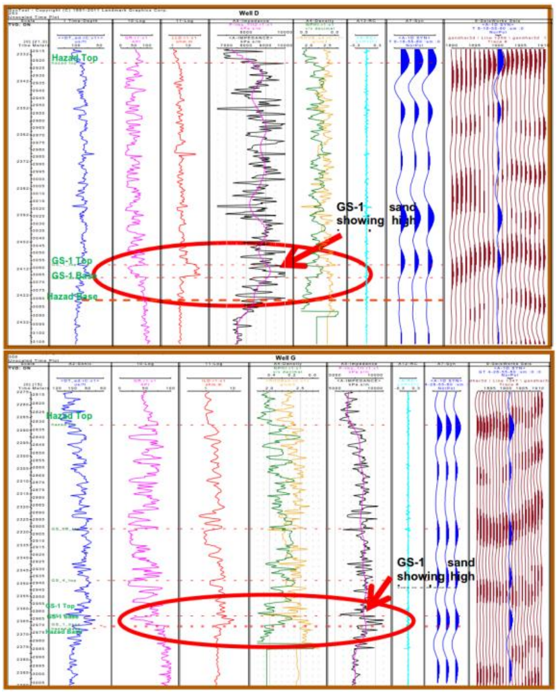

Figure 4: Synthetic seismograms for wells D and G showing Electrolog properties across Sand GS-1.

In this area, GS-1 sand has maximum effective thickness of 4-5m which is marked by a thick shale unit deposited at the bottom and thin shale unit at top. Upper part of GS-1 sand is porous and characterized by low impedance. Bottom part of GS-1 sand is fine grained, compact and shows high impedance. Impedance curve filtered at seismic frequencies shows overall high impedance which is more than that of the overlying and underlying shale units (Figure 5).

The above argument is made use of in the study to delineate GS-1 sand in the impedance volume obtained after carrying out seismic inversion in HRS software. In the impedance volume GS-1 sand is seen to have higher impedances >8900 units as compared to the overlying and underlying shale which are of lower impedances. As GS-1 top is not a correlatable seismic event (Figure 6), selecting a suitable and accurate window for deriving the above attributes corresponding to the unit has been an issue.

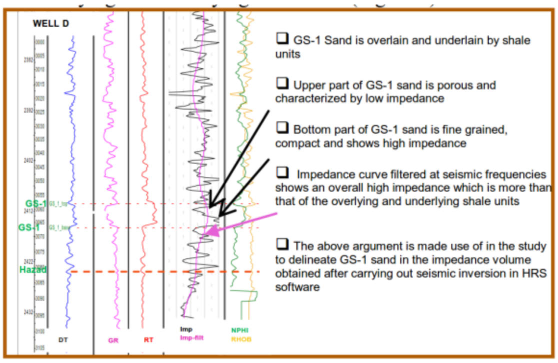

Figure 5: Electrologs of well D showing Impedance variation across Sand GS-1.

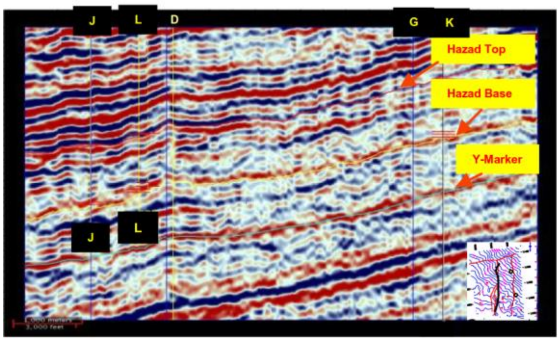

Figure 6: Arbitrary line passing through wells J, L, D, G & K

Inversion brought out clear definition of Hazad base as underlying Cambay shale impedance is substantially lower than the overlying sediments (Figure 7).

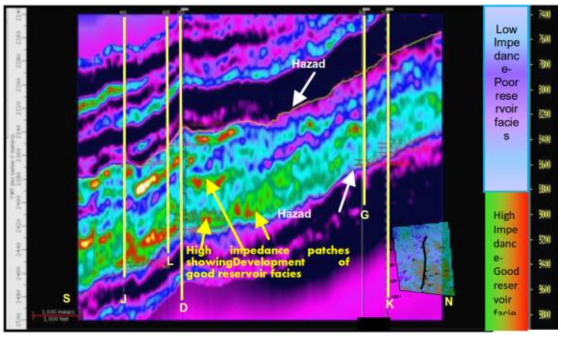

Figure 7: Impedance section along RC line passing through wells J,L,D,G & K

The bottom of GS-1 sand, marked by the occurrence of high reservoir impedance of the unit, was tracked manually in the impedance volume. Time thickness derived for GS-1 unit at well locations was another Q.C. factor for correlation of GS-1 sand top. Keeping the time thickness of GS-1 at well locations as primary factor, the two way time surface for GS-1 top has been constructed in the seismic data (Figure 8).

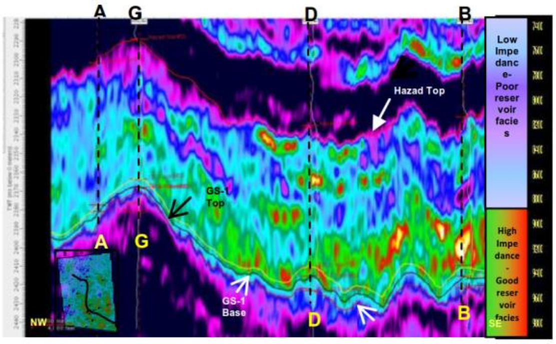

Figure 8: Impedance section along RC line through wells A,G,D & B Showing GS-1 Top and Base

Time and Structure maps of GS-1 sand unit were successively prepared along with faults and studied for the structural configuration (Figure 9a, b). The sand distribution has been brought out by taking mean amplitude slice in impedance volume between GS-1 top and base horizons (Figure 10). Areas of Higher impedance values (>8900) are indicative of better reservoir facies. On the acoustic impedance slice it was identified that GS-1 sand facies is well developed near the wells D, L, M, N, I, J whereas wells C, F, E, G, A, K, B and H fall in area characterized by poor reservoir facies. The study has clearly brought out the differentiation between good and poor reservoir facies.

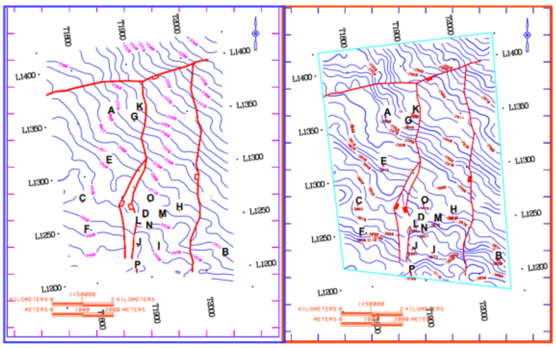

Figure 9(a): Time Map at GS-1 Top (b) Structure Map at GS-1 Top

The present facies map explains the GS-1 sand distribution encountered in most of the wells in the study area. In addition to better reservoir exploitation, the study leads towards suggesting new areas/locales for exploring the producer sand in the north and east of the established field.

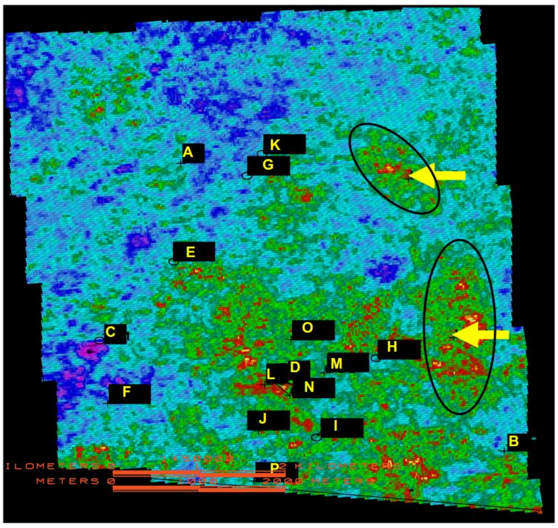

Figure 10: facies map of GS-1 sand unit

## Conclusions

Model based inversion has emerged as potential tool for interpreters to define the reservoir geometry and quality with confidence. Inversion has successfully brought out the precise sand geometry of GS-1 pay sand. The discrete nature of reservoir sands of GS-1 pay sand has been brought out with confidence. The geometry worked out for this reservoir has shown a large exploration potential. These techniques can be used for mapping thin sands occurring in clastic basins.

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