Confounding Effects Of Coals On Deeper Seismic Imaging - A Case Study from East-Sobhasan-Langhnaj field, Cambay Basin, India

R. Vig1, V. Singh2, D. N. Tiwari2 & A. K. Bansal1

1 A & AA Basin, ONGC, Jorhat
2 GEOPIC, ONGC, Dehradun

ABSTRACT: Exploration for hydrocarbons in Cambay basin has reached a mature stage, where almost entire area has been covered with seismic survey encompassing both 2D and 3D data. Seismic data has played an important role in understanding the petroleum habitat of the basin. In spite of tremendous efforts, exploration of deeper pays in north Cambay basin has been a major challenge due to presence of overlying thick coal units. These coal units act as transmission filter, generate interbed multiples and mode conversions, alter the wavelet shapes. In order to understand the seismic response of deeper pays, elastic modeling was carried out at several well locations in the study area which suggests that conventional 3D seismic data is not adequate to meet the objective of delineation of reservoir sands as the seismic response of these reservoir sands is very feeble and is contaminated by the presence of multiples and mode conversions. These modeling results also show that there is a very strong mode conversion from top and base of the different coal layers. This indicates that multi-component seismology may be good candidate for exploration of these pays.

INTRODUCTION

The Cambay basin, Gujarat, India is heading towards maturity with conventional exploration methods. 2D and 3D P-wave seismic data integrated with well data have established about one fourth of prognosticated reserves. As all the easy to find oil has already been discovered, now the challenge has been to explore subtle traps thereby arresting this maturity trend. It has become necessary to utilize the new emerging technologies like multi-component, 2D, 3D and 4D surveys, prestack depth imaging, prestack attribute analysis (AVO), post stack inversion and geostatistical reservoir characterization etc. They will be highly useful in deciphering each and every aspect of reservoir vis a vis its petrophysical properties which are required to be known before actually drilling the well. But before applying any new technology, it is very important to critically examine its worthiness in the given setup, because every area has unique geological setup and hence a unique type of problem for which same solution may not work. This warrants rigorous modeling studies using available geoscientific data. This may help in understanding the intricacies of the area and in achieving exploration objectives through effective application of emerging technologies.

In this paper authors have taken a case study of Langhnaj-East Sobhasan field of Cambay basin where rigorous elastic modeling study was carried out to analyze the seismic response of reservoir sand and they were used for interpretation of real seismic data. Synthetic seismic response of the pay sand was generated using electrolog data of drilled well-A, and various factors were altered to see its effect on the synthetic. The seismic responses were simulated by altering frequencies, pay thickness, effect of multiples and mode conversion, at the well and correlated with the actual P-wave seismic data acquired. Although, the actual process of seismic imaging cannot be mimicked, due to so many assumptions made at so many steps of data acquisition and processing, but still an approximation can be made by the help of robust modeling techniques and many of the inhibitions for using new technologies can be reduced.

GEOLOGICAL BACKGROUND

The study area falls in Langhnaj-East Sobhasan field of Mehsana-Ahmedabad tectonic block of Cambay basin (Fig. 1). The general stratigraphy of the area is shown in Fig-2. The Olpad Formation is the first sedimentary sequence after the igneous lava flows consisting of primarily the trap derivatives deposited over undulating surface in fluvial to swampy regime mainly in paleoflows during Paleocene. The overlying Older Cambay Shale consisting of thick monotonous fissile shale was deposited during Early Eocene in major transgression from south. The overlying Kadi Formation in this area is stratigraphic equivalent of Younger Cambay Shale, and is further subdivided into Mandhali, Mehsana and Chhatral members comprising of sand shale alterations intervened by thick coal seams deposited under fluvial conditions. Overlying this is Kalol Formation deposited in fluvial environment consisting of sand-shale sequences having...
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thick coal seams. Kalol and Kadi Formations contain the main hydrocarbon bearing sands in the area, which also contain thick coal seams thereby obscuring the reflections and causing lot of multiple activity. Delineating sands within Mandhali Member lying below thick Kalol, Chhatral and Mehsana coals is the major task, and the present study is confined to that.

COAL RELATED CONTRIBUTIONS TO THE ELASTIC WAVEFIELD

It is well known that coal reflectors having density of the range of 1.2 to 1.8 gm/cc and P-wave velocity of the range of 1800-2500 m/s give rise to whopping reflection coefficients (often 0.4 or greater) and have very large influence on the recorded wavefield. As coals layers are highly heterogeneous, a full description of coal-induced contributions to the wave field would lead to more complicated scenario and it may not be possible to visualize them clearly. We are considering here following events: (a) P-wave reflection train from the coals, (b) mode converted reflections, (3) peg leg multiple generated by thick and thin coal reflectors and (d) wavelet at the target level which has been modified by the short period interbed multiples after two way passage through the coals. Strong side–lobe energy produced by the booming primary coal reflections impede interpretation by tuning with the zone of interest wavelet in the case where target is just located below the coals. Depending on the strength of the side lobes, this tuning may pose more problem than transmission loss. The presence of thick coal units in the study area certainly generate the peg-leg multiples. Then attenuating these multiples on the basis of differential move out with offset or periodicity is not possible at all. The mode-converted reflections often exhibit characteristics of multiple energy on recorded seismic data. They also cannot be removed during processing and generate false AVO anomalies in any prestack analysis of the data. Final significant coal related phenomena is the transmission loss introduced at the coal interfaces which diminishes the amplitude and alters the wavelet shapes significantly. Most often, this leads to misinterpretation of seismic attributes used for reservoir characterization.

ELASTIC MODELING STUDY

In order to understand the effect of Mandhali pay sands on seismic reflection response, which are lying under the thick coal units of Mehsana, Chhatral and Kalol, synthetic modeling was carried out. Sonic and density logs of wells were taken up for detailed modeling studies using Hampson-Russel AVO modeling package. As shear wave log was not available, computation of shear wave velocity was made using Castagna empirical relationship. Synthetic gathers for primaries only as well as gathers with primaries, multiples and mode conversions were also generated. After application of NMO corrections, these gathers were stacked and compared with real seismic data.

Modeling was carried out at few wells of the 3D area and here results of modeling exercise at well-A are presented.
The thickness of pay sand at well-A is 8m and the overlying coal seams are 2 – 20 m thick. As a first step synthetic response was generated with primaries only, then with multiples and mode conversions and then this was compared with the seismic. To analyze the detectability of this sand, thickness of this sand was artificially increased to 16, 24 and 40m and synthetic responses generated using statistical wavelet extracted from real seismic data. Further to see the effect of frequency, the standard Ricker wavelet of 20, 30, 40, 50 and 60Hz were used to generate synthetic seismic responses.

**DISCUSSION**

Main objective of acquiring seismic data in the area was to delineate Mandhali sands which occur at relatively deeper level and are overlain by thick coal beds. Modeling was carried out, so that the effect of multiples, mode conversion, impedance contrast of the sands and their synthetic response varying with frequency and thickness can be brought out. At well-A modeling results show multiple activity and the reflection events generated from the coal interfaces are consistent in synthetic as well as in real seismic data (Fig. 3). Synthetic response of primaries only, i.e. in the absence of multiples, shows the high amplitude reflections from Mehsana coals which are lying below thick coals of Kalol Formation, indicating substantial transmission of P-wave energy below these thick Kalol coals which are supposed to be the main cause of multiple generation. When multiples and mode conversion is taken into consideration the synthetic seismic response of these high amplitude Mehsana coals underlying Kalol coals gets diminished, there by indicating considerable mode conversion of the energy at above lying high impedance boundaries (Kalol coals) (Fig. 3). It is imperative from this that when such strong reflections of coals below Kalol coals are getting deteriorated, detecting low impedance sands below will be almost impossible by conventional methods. Another factor responsible for seismic resolution is the dominant frequency, so its effect was also studied by altering frequencies and generating synthetic seismic response. By increasing frequencies from 20Hz to 60Hz modeling with primaries only and using Ricker wavelet, it is seen that detectable response of the pay sand is visible beyond 40Hz only (Fig. 4 & 5), and when statistical wavelet is used with primaries only there is no discernable response observed. Similarly when we introduce the effect of multiples and mode conversions the response of this sand becomes more composite (Fig. 4). One more factor which effects seismic resolution of beds is their thickness, so that was also attempted. When the thicknesses of the sand was artificially increased, using statistical wavelet extracted from the seismic data and considering primaries, multiples and mode conversions for generation of synthetic gathers, it was observed that even larger thicknesses also are not able to generate a detectable response because of low impedance contrast (Fig. 6).

![Figure 3: Effect of multiples and mode conversion on seismic response at well-A](image-url)
Figure 4: Synthetic response of pay sands with different frequencies

Figure 5: Synthetic response of pay sands with different frequencies
The Mandhali sands in well-A have very low impedance contrast and are below seismic resolution limit, therefore will generate very feeble composite seismic response. As discussed above and proved by modeling interference of primaries, multiples, mode conversions and seismic noise further complicate the recorded seismic signal. Considering all this it makes it difficult to analyze the generated composite seismic response of individual reservoir facies and some better strategy has to be evolved for exploration of these reservoirs.

Modeling results have shown a significant amount of P to S mode conversion from top to bottom of thick coal units, which can be utilized for better subsurface imaging through recording of multi-component seismic surveys. However, prior to attempting an expensive multi-component seismic survey, it is worthwhile that 3-Component offset VSP’s is recorded in some of the wells alongwith full wave sonic recording to further reaffirm the mode conversion aspects by further modeling exercises.

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