GEO India 2011

Full Paper

Control Id: 634

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Interpretation of 3D Seismic Data for Thin Coal Seam for Underground Coal Gasification – A Case Study from Mehsana, India

Abstract

During hydrocarbon exploration in north Gujarat, India ONGC discovered huge reserves of coal at various depths ranging from 700 to 1700 m within hydrocarbon bearing formations. Since, these coal seams cannot be exploited by conventional mining methods, underground coal gasification was considered. To predict the extension and structure of the coal seams encountered in information well U-1, suitable for gasification 3D seismic data were acquired and processed by ONGC in the Mehsana city area post stack migrated output was interpreted during the late eighties.

This paper deals with interpretation of the 3-D seismic data, the maiden in-house 3-D seismic data interpretation by ONGC in India. The Eocene coal seams, S-I and S-III were identified on the 3-D seismic data through VSP data at U-1. Tops of these coal seams were correlated through vertical sections and times slices. TWT maps were prepared and converted to depth maps using VSP velocity function at well, U-1.

The top of S-I is identified and mapped accurately. The bottom could not mapped as the thickness is below resolution (λ/4 is 12.5) of the data set. An approximate thickness of S-I was prepared using amplitude attribute. S-III being too thin (6.25 m at U-1), its top could not be resolved by seismic data set. Therefore a horizon close to top of S-III was mapped using seismic data and subsequently corrected by incorporating well data for preparing depth map of SIII top

3-D seismic maps of coal seams S-I and S-III led to shifting of earlier proposed location (U-2) from disturbed zone to a suitable location (U-3) in the western part, where coal seams are also sufficiently thick. The depths and thickness of target coal seams predicted by 3-D seismic interpretation are close to those encountered in the well U-3, drilled subsequently.

This case study highlights the successful use of 3-D seismic in the selection of an appropriate area foe UCG pilot project.

Introduction

During hydrocarbon exploration in the Ahmedabad - Mehsana block of Cambay basin in the western part of India (Figure 1) ONGC discovered huge reserves of coal at various depths ranging from 700 to 1700 m within hydrocarbon bearing formations. Since, these coal seams cannot be exploited by conventional mining methods, underground coal gasification was considered in the Mehsana city area in this block.

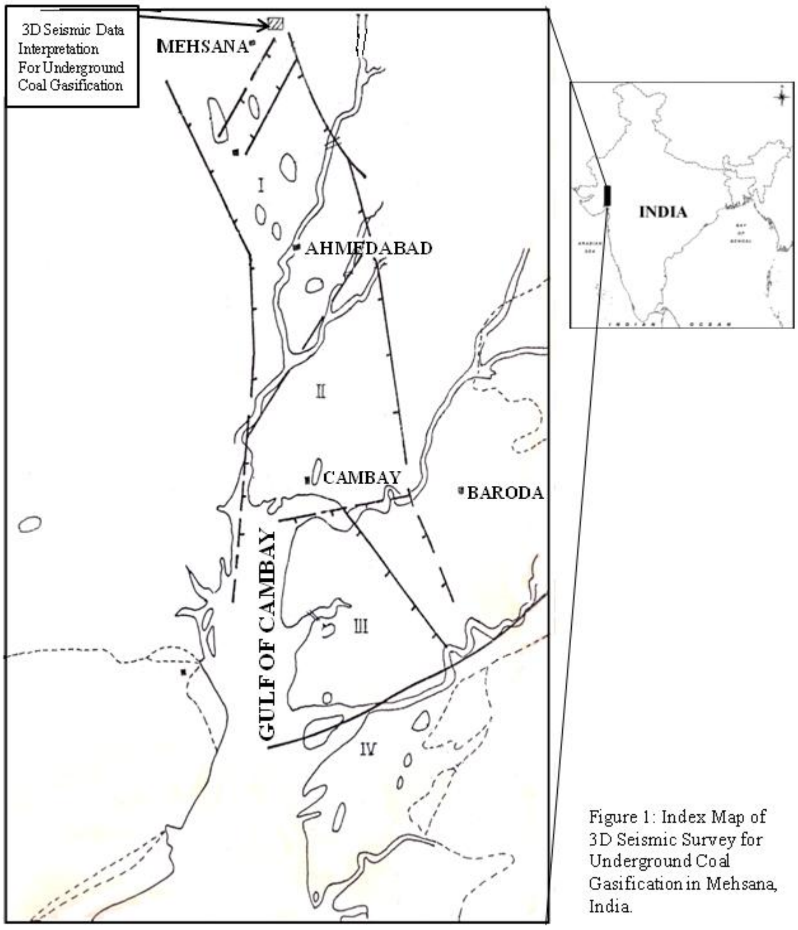

Figure 1: Index Map of 3D Seismic Survey for Underground Coal Gasification in Mehsana, India.

An information well U-1 is located on the rising eastern flank of the Cambay basin between wells M-2 and M-3 (Figure 2) in Ahmedabad - Mehsana block. The entire sedimentary column from Upper Jurassic to Recent thins out towards east and has been affected by a number of down-to-basin faults. Data of the three drilled wells in the area of present study establish thinning of the stratigraphic column below Upper Eocene and absence of most of the coal seams towards east. Out of several coal seams of early and middle Eocene age, S-I and S-III were initially considered for pilot experimentation of underground coal gasification due to their thinness and geo-hydrological conditions therein.

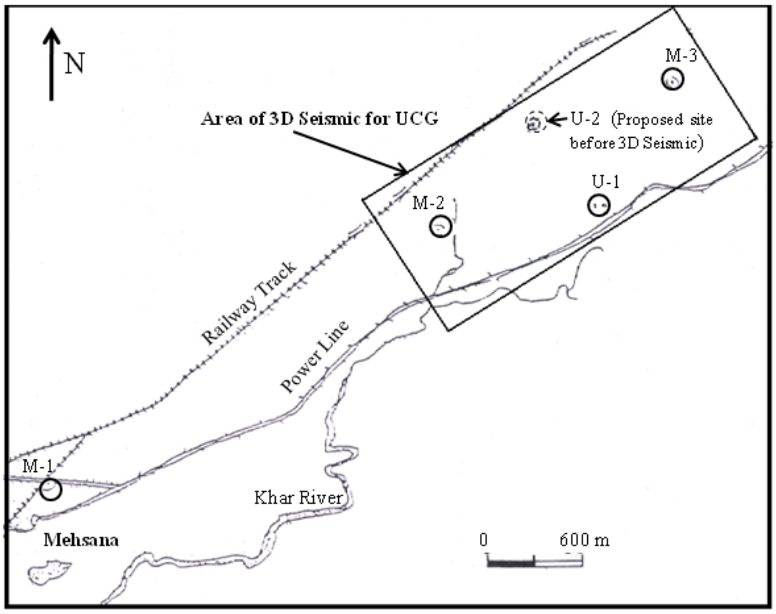

Figure2: Location Map Showing Area of 3D Seismic and Wells.

To decipher structural set up and details of small scale faults, which were important before taking up underground coal gasification, 3D seismic data were acquired and processed by ONGC. This paper deals with interpretation of the 3-D seismic data for these coal seams. Incidentally, this was the first / maiden in-house 3-D seismic data interpretation by ONGC in India.

Geological Set-up:

Present study area is in the northern part of Ahmedabad - Mehsana tectonic block on the rising eastern flank of Cambay basin. A number of coal seams are developed in the Kadi and Kalol formation of early and middle Eocene age in this block. However, development of coal seams is significant in the Mandhali Member of the Kadi formation, where the coal seams comparatively thin. The entire sedimentary column from Upper Jurassic to Recent including the Kadi formation thins out towards east and has been affected by a number of down to basin faults. The stratigraphic succession of well U-1 is given in Figure 3. As per the data of

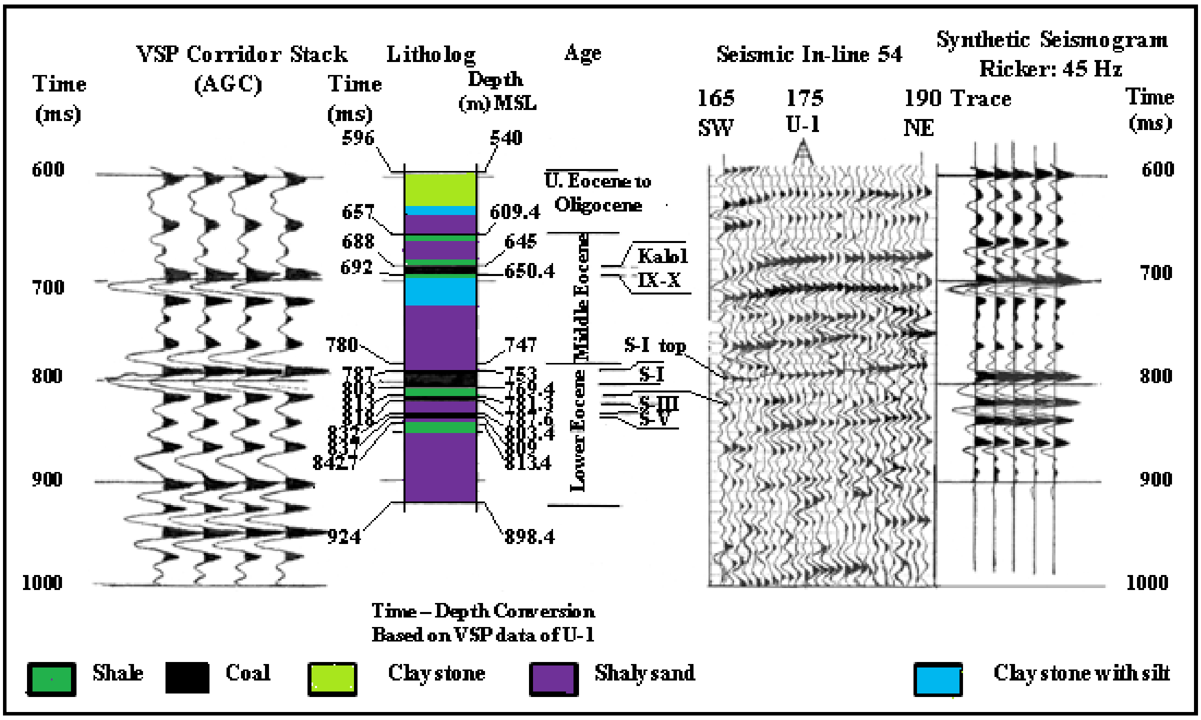

Figure 3: Litho-stratigraphic Correlation with VSP Corridor Stack, Seismic Section and Synthetic Seismogram at well, U-1.

the three drilled wells in the area of present study the thinning of the stratigraphic column below Tarapur formation towards north-east and absence most of the coal seams towards the well M-3 are pronounced.

Acquisition and Processing

48-fold 3-D seismic data were acquired in the area selected for underground coal gasification (UCG) pilot project by using a four line swath with 192 channel asymmetrical split-spread configuration, a group interval of 30 m, line spacing of 120 m, a vibrator source and sampling interval of 2 ms (Mishra et. al., 1988). Processing of the 3-D seismic data which is the first of its kind in India is discussed by Sen et al., 1990. The key processing steps are interpolation of the data acquired in CDP bins from 15 m x 60 m to 15 m x 30 m, 3-D bin sorting, 3-D velocity field generation, 3-D residual statics, 3-D DMO stack and 3-D Finite Difference Migration (two passes).

Interpretation

The seismic data volume was interpreted in an IIWS. A movie of all vertical sections and time slices was generated to have a general impression of faults; direction, dip and strike of the horizons; culminations of structure, etc.

The In-line 54 and Cross-line 213 was tied with well U-1 through VSP and synthetic seismogram and the tops of S-I and S-III were identified on these lines (Figure 3). The horizons corresponding to S-I and S-III were correlated through vertical sections at an interval of 250 m through loop ties to use them as control lines. The horizons were identified on time slices through Edge Displays (Figure 4). The tracked horizons were verified on the

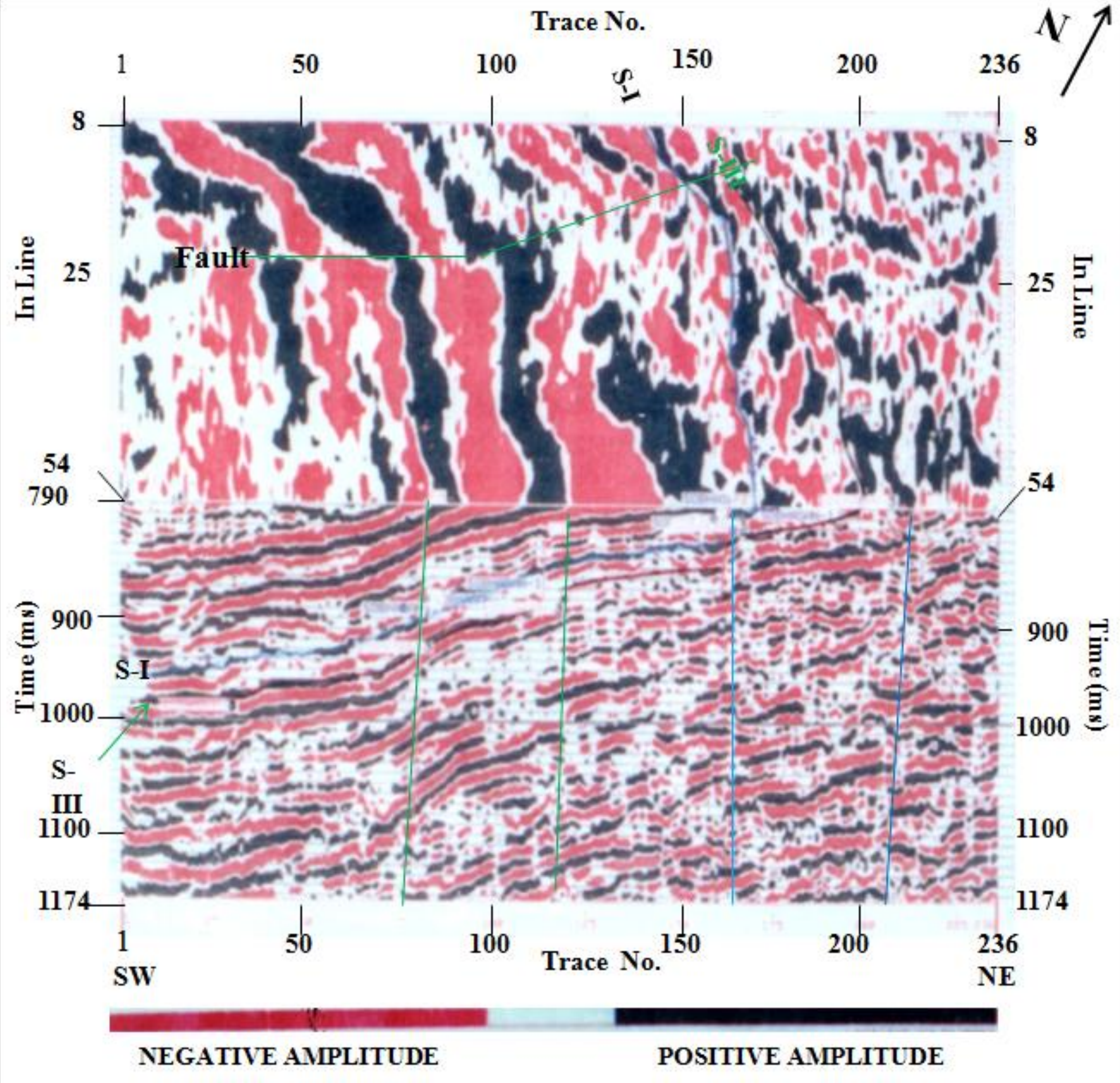

Figure 4: Edge Display: Inline 54 at The Intersection of Time Slice at 790 ms.

control lines, again through Edge Displays (Figure 5). After establishing interpretation on the control lines, the correlation was carried out from time slice to time slice, and Two Way Time (TWT) maps pertaining to tops of S-I was prepared (Figure 6). The top of S-I could be mapped accurately. The bottom could not be mapped as thickness of S-I is below resolution limit ($\lambda/4$ = 12.5). Top of S-III (6.25 m thick at U-1) could not be resolved seismically.

Therefore, a horizon close to top of S-III was mapped using seismic data (Figure 7). The

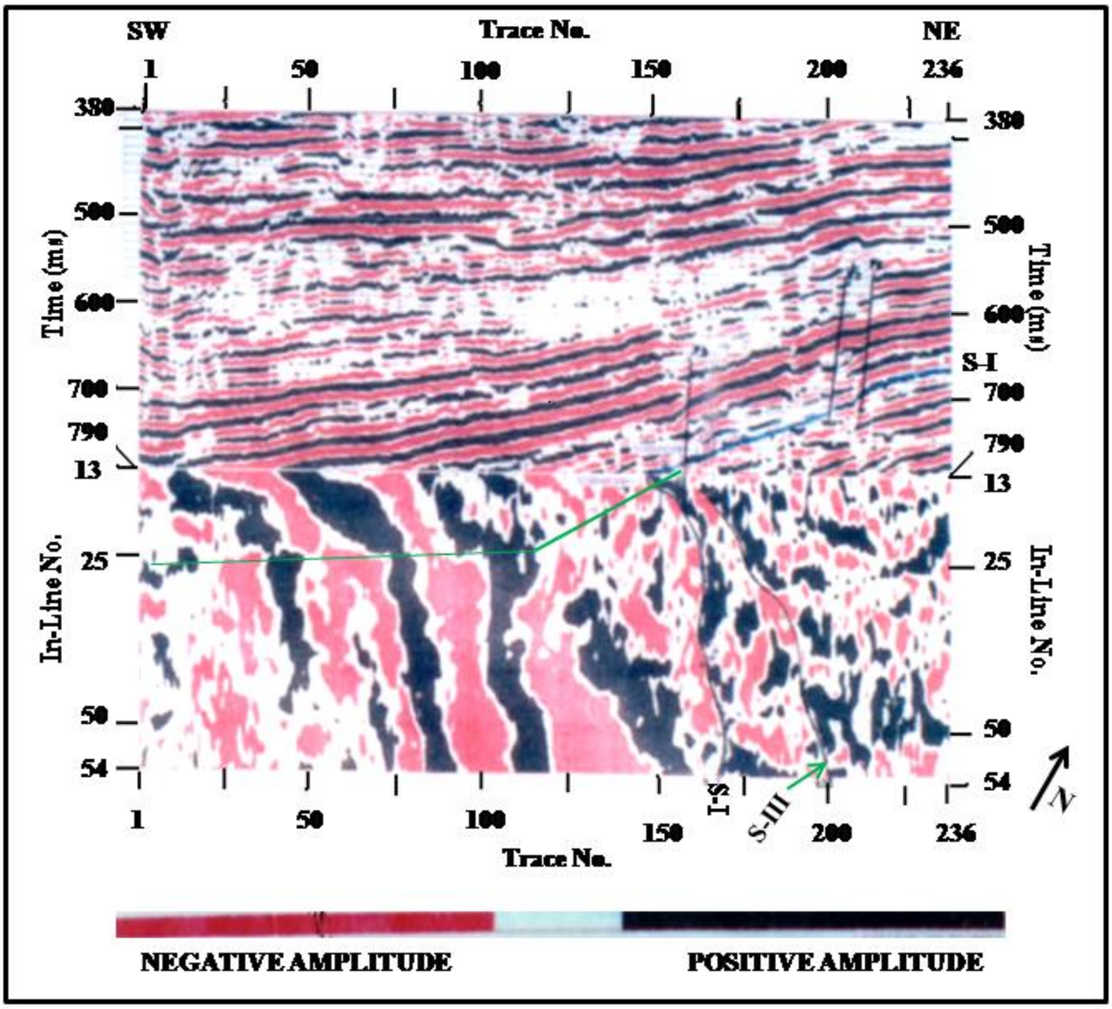

Figure 5: Edge Display: Time Slice 790 ms at The Intersection of In line13

depth maps pertaining to S-I top (Figure 8) was prepared by using VSP velocity function at

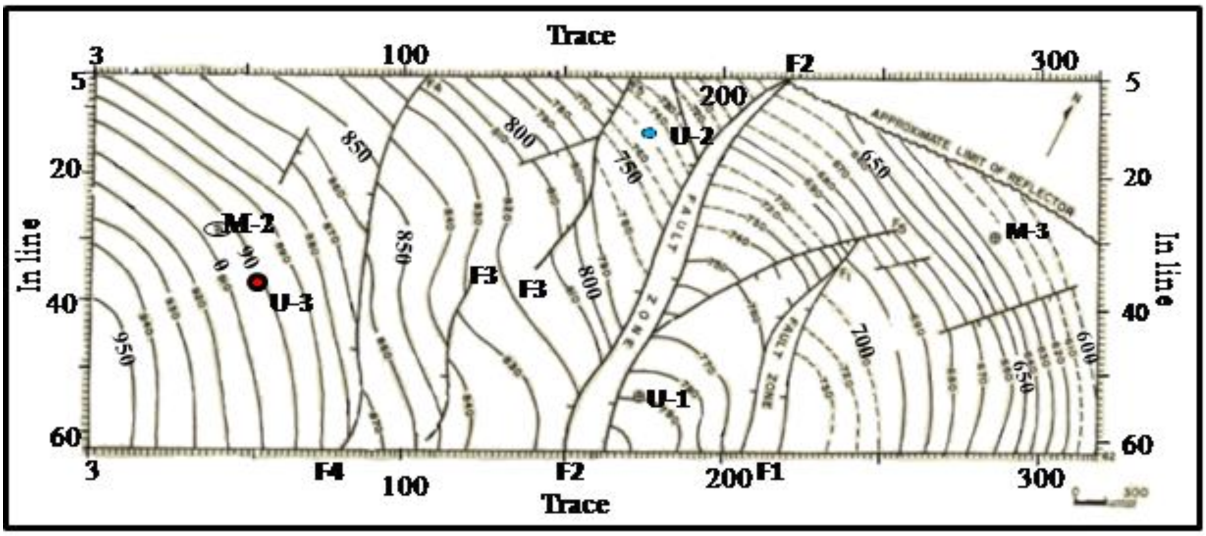

Figure 6: Two Way Time Map on Horizon S-I. U-2, the Proposed Location before 3D Seismic Interpretation Was Shifted and Drilled at U-3 on The Basis of 3D Seismic Interpretation.

well U-1, and map on top of S-III (Figure 9) was obtained by subsequent incorporation of data of wells, M-2 and M-3.

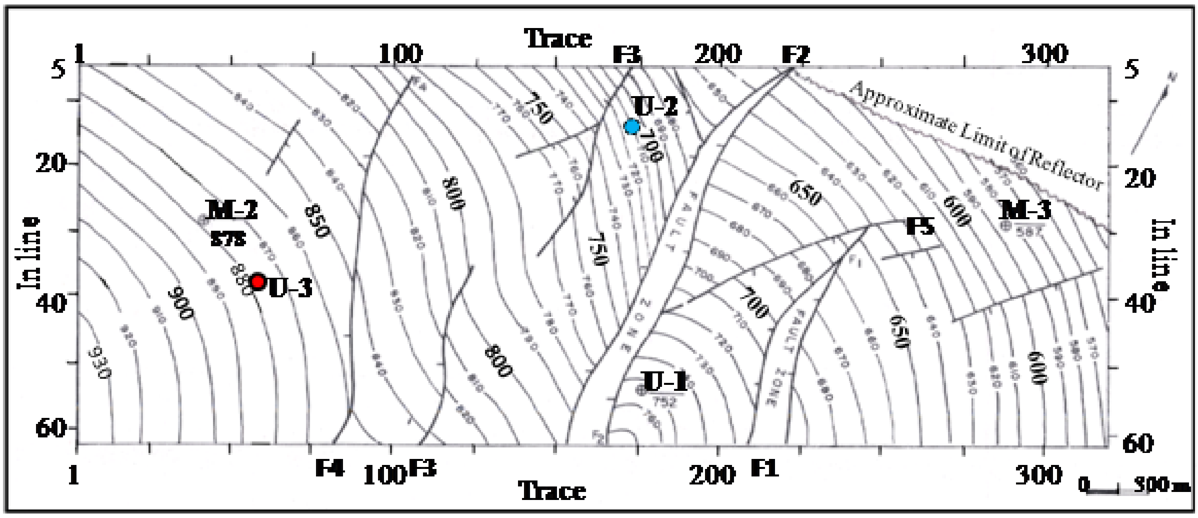

Figure 7: Depth Map on Horizon at Top of S-I Coal Seam. U-2, the Proposed Location Before 3D Seismic Interpretation was Shifted and Drilled at U-3 on the basis of 3D Seismic Interpretation. Depth Predicted by 3D Interpretation is Close to Results of Subsequent Drilling at U-3. See Table 1.

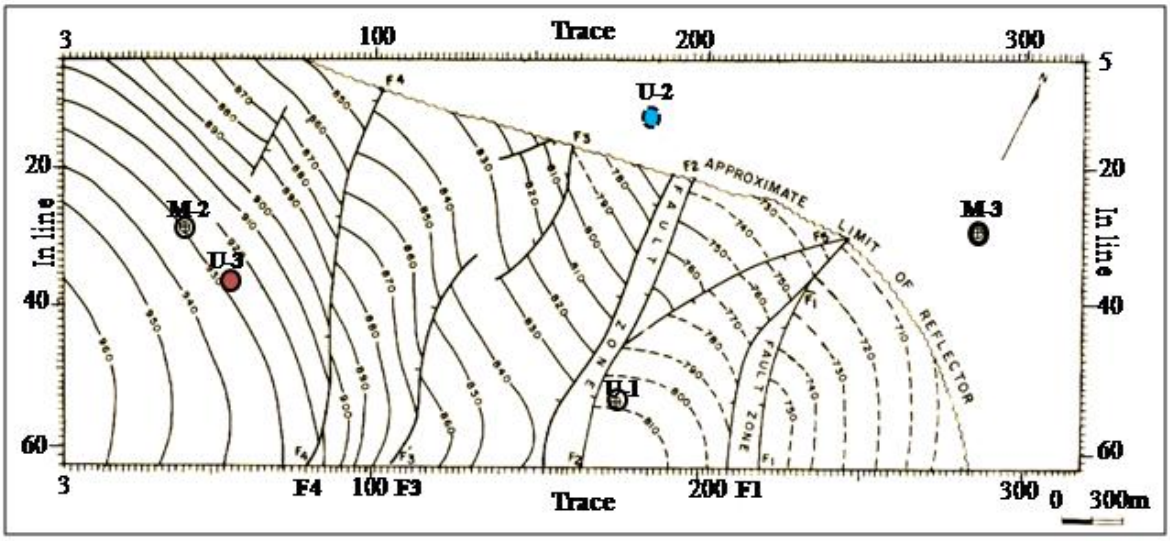

Figure 8: Two Way Time Map on Horizon S-III. U-2, the Proposed Location before 3D Seismic Interpretation was Shifted and Drilled at U-3 on the basis of 3D Seismic Interpretation.

Since, the bottom of S-I could not be mapped due to resolution limit, thickness map of S-I was attempted on the basis of seismic amplitudes on the top of S-I (Figure 10), and their calibration with the thicknesses of S-I coal seam encountered in the wells M-2, U-1 and M-3 (Figure 11). Highest amplitude is observed on the rising flank and south west of M-3 and is attributed to tuning thickness effect (Brown et al, 1986). Thus, the approximate thickness map was prepared applying the relationship derived from the well data and tuning thickness concept (Figure 12).

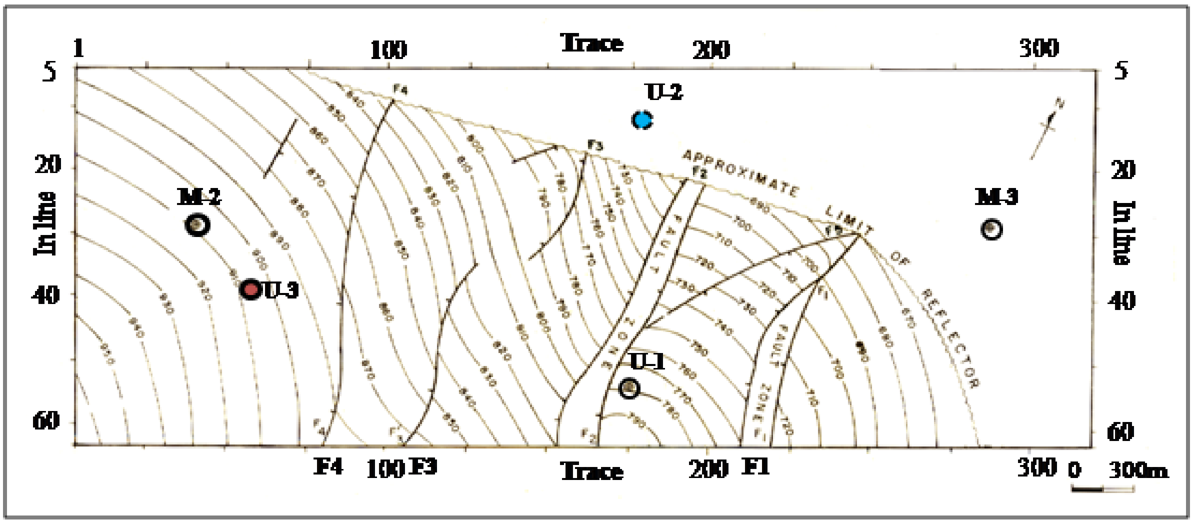

Figure 9: Depth Map on Horizon at Top of S-III Coal Seam. U-2, the Proposed Location before 3D Seismic Interpretation was Shifted and Drilled at U-3 on The Basis of 3D Seismic Interpretation. Depth Predicted by 3D Interpretation is Close to Results of Subsequent Drilling at U-3. See Table 1.

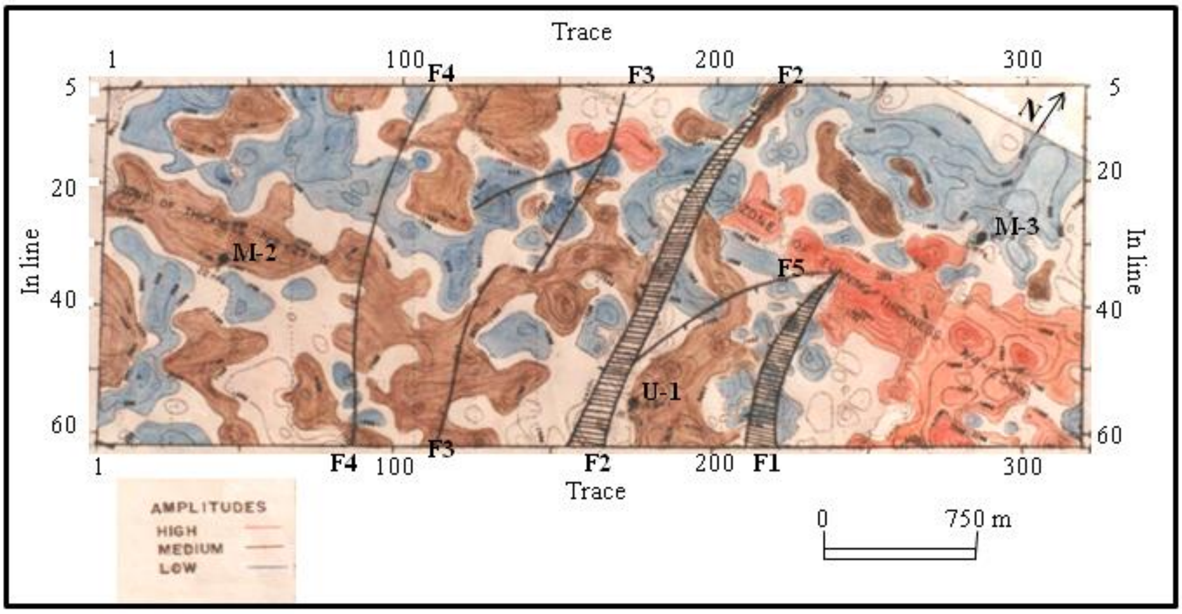

Figure 10: Absolute Amplitude Map on Horizon S-I. The Amplitude Values were Categorized into High, Medium and Low for Correlation with Thickness of S-I Coal Seam.

Results and Discussions

The TWT and depth contour maps (Figures 6 to 9) show that both S-I and S-III tops become shallow towards the east i.e. towards basin margin. The depth to the tops of S-I varies from 930 m in the west to 510 m in the east (Figure 8). Though the top of S-III could not be mapped due to lack of resolution, a surface near to it could be mapped and depth map of S-III was prepared by incorporation of well data into the said map. The depth to the top of S-III varies from 960 m in the west to 670 m in the east (Figure 9). This horizon does not extend up to well, M-3. Both S-I and S-III are shallower towards north-east.

There are 5 main faults viz. F1, F2, F3, F4 and F5 (Figures 6 to 9). Out of these the F1 and F2 are close to well U-1, which proposed for underground coal gasification before this interpretation. Throws of these faults varies from 25 m in the south to 10 m in the north at S-I and S-

III tops. Other faults have throws between 5m and 10 m. Other faults have throw between 5 m and 10 m.

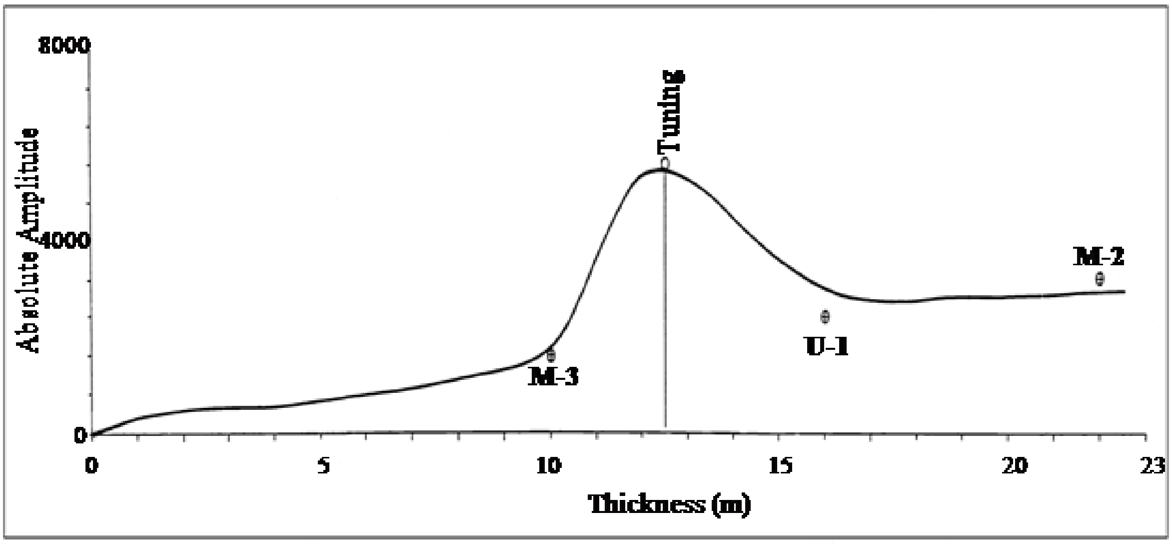

Figure 11 : Cross Plot of Absolute Amplitude Versus Thickness of S-I Coal Seam at well locations.

The location of well U-2, proposed to be drilled for coal gasification before this interpretation is also in a fault zone. Moreover, the depth maps show both S-I and S-III are likely to be absent in U-2. It is observed that western part of the area near M-2 is free from faults and the thicknesses of coal seams are more. Therefore, the well was drilled at the new location U-3. The results of drilling vis-à-vis predicted by 3-D seismic interpretation at well U-3 is given in Table-1, which shows the accuracy of prediction of depth to top of S-I and S-III are 1.4 m and 0.4 m respectively; and that of thickness of S-I is 1.5 m.

Table 1 Comparison of predicted and drilled depths and thickness of coal seams in well, U-3.

Coal seam	**Predicted by 3D seismic interpretation (m)**	**Drilled results (m)**	**Difference of drilled results from those predicted (m)**
Depth to top of S-I coal from MSL (m)	880.5	879.1	-1.4
Depth to top of S-III coal from MSL (m)	909.0	908.6	-0.4
Thickness of S-I coal (m)	20.5	19.0	-1.5

Conclusions and Recommendations

On the basis of interpretation of 3D seismic data, it is known that the well U-2 proposed (prior to this interpretation) for drilling and the drilled information well U-1for underground coal gasification are in a fault prone zone and likely to cause leakage of injected air and steam as well as the flue gases resulting from the UCG process. Also, presence of the coal seams is unlikely at the location of U-2. Therefore, the well was relocated and drilled in a safe location as U-3.

The results of drilling of U-3 show that the prediction of depths and thicknesses of target coal seams by this first ever 3D seismic data interpretation in India was precise. This enhanced the confidence to take up subsequent in-house 3D seismic interpretation.

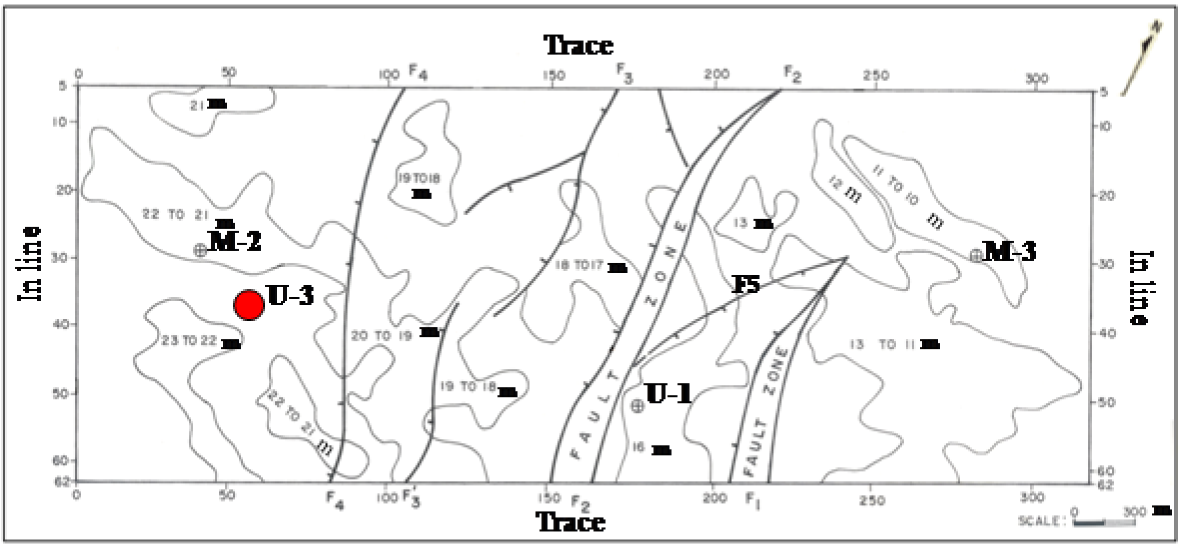

Figure 12: Thickness Map of S-I Coal Seam based on Amplitude Map (Figure 10). Thickness Predicted by 3D Interpretation is Close to Results of Subsequent Drilling at U-3. See Table 1.

Acknowledgements

The authors thank ONGC for giving them the opportunity to carry out first ever in-house 3-D seismic data interpretation and permitting them to submit this paper for publication. They thank Gurucharan Singh , now retired from ONGC for valuable discussions during this work. They also thank S. Chandrasekaran of ONGC for valuable discussions during the preparation of the manuscript and V.B. Singh of ONGC for critical review and suggestion during the final stage of the manuscript. The views expressed in this paper are of the authors and need not be those of ONGC.

References

Brown, A. R., Wright, R. M., Burkart, K.D., Abriel, W. L. and Mc Beath, R.G., 1986, Tuning Effects, Lithological Effects and Depositional Effects in the Seismic Response of Gas Reservoirs, Geophysical Prospecting, vol. 34, pp. 623-647.

Mishra, S., Marwah, L. K. , Pandey, U. S. D., Sankar, T. and Singla, S. N., 1988, 3-D Seismic Survey Enters in Field of EOR and Underground Coal Gasification, Journal of Association of Exploration Geophysicists, vol. IX, No. 2, pp. 57-70.

Sen, G. and Babbanjee, 1990, Methodology Formulation of 3-D Seismic data Processing and its applications, Journal of Association of Exploration Geophysicists, vol. XI, No. 2, pp. 69-80.