Field Depth Conversion Using Seismic Inversion

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Summary

Derived seismic attributes can be used as geological guide for meaningful depth conversion apart from being used for reservoir characterization. Velocity the important component in depth conversion can be constrained as a function of one or more attribute as variables for linear or multi-linear regression (V=aX+bY+cZ….).

This paper discusses a full field depth conversion technique using average velocity from wells and an Acoustic Impedance volume derived from seismic inversion and its application in the Panna Field offshore of western India.

Introduction

A fully calibrated Acoustic Impedance (AI) volume addresses the velocity variations both laterally and vertically.

$AI = \rho * V$ .... (1)
ρ is density and V is interval velocity

In areas of poor well control, velocity derived directly from the impedance volume may not be valid as density can not be determined uniquely. Instead of using velocity backed out directly from impedance, the impedance can be used as a guide to propagate well velocities away from well locations to address lateral velocity variations. In the case study to be discussed over Panna Field, such lateral velocity variations exist because of three separate intervals of carbonates.

The robustness of the method lies in the fact that the impedance volume is derived from the well data and seismic data by proper conditioning in the form of check-shot calibration, sonic & density log editing, low frequency modeling and seismic inversion. (Figure-1a & 1b show a typical workflow involved in Inversion). Though the inverted data may not give absolute values for density and velocity separately it does give relative variations laterally. The quality of depth conversion depends on the quality of inversion volume.

This approach may not provide an absolute solution but it is worthwhile to attempt with other depth conversion methodologies to understand their sensitivities. The method gives a handle on the trend of the errors, and geostatistical mapping using variogram analysis should be a preferred method to trend-fit the errors.

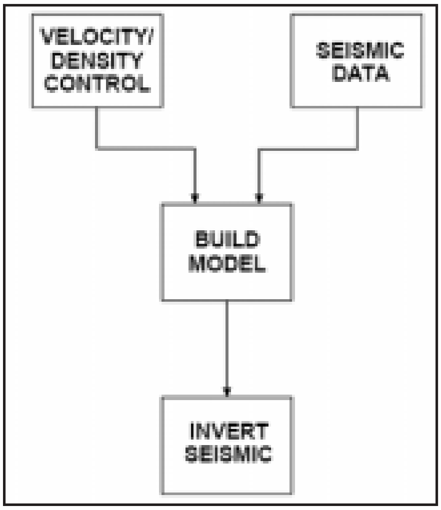

Fig.1a: (*Courtesy Hampson Russell*)

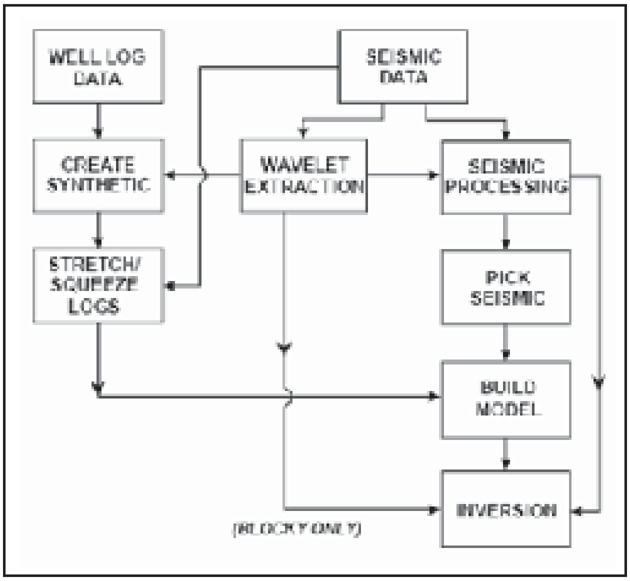

Fig. 1b: (*Courtesy Hampson Russell*)

Method

V α AI .... (2)

V and AI can either be interval velocity and interval AI within a layer or average velocity & average AI from a datum to horizon of interest.

Regression of V (Velocity from wells) on AI (Acoustic Impedance from inversion volume at well location) from few representative well locations within the field would result in a straight line equation. This equation can be used to predict velocities away from well locations using AI values as input.

Application

The Field

The Panna Field offshore of western India is located about 95 Km northwest of Mumbai (Figure-2). Panna contains oil and gas within the Bassein Formation Limestone of Eocene/Oligocene age (general stratigraphy shown in Figure-3).

The challenge

Bassein reservoir in Panna has only a 20 m oil column between a gas cap and an aquifer. More than 80 wells have been drilled within the crestal part of the field (Figure-4). The challenge is to place new horizontal wells based on Time-Depth conversion in the flank areas where the oil column thickness reduces to 10-12 m and there is little well control. An error of 10m in depth conversion would result the wells to be placed in the water leg or a layer above reservoir, both of which are not desirable.

The Issues

An east-west acoustic impedance cross section across Panna (Figure-5) shows the lateral variations existing in the field.

The points to note are the Massive Carbonates of Miocene age in the shallower section which pinches out

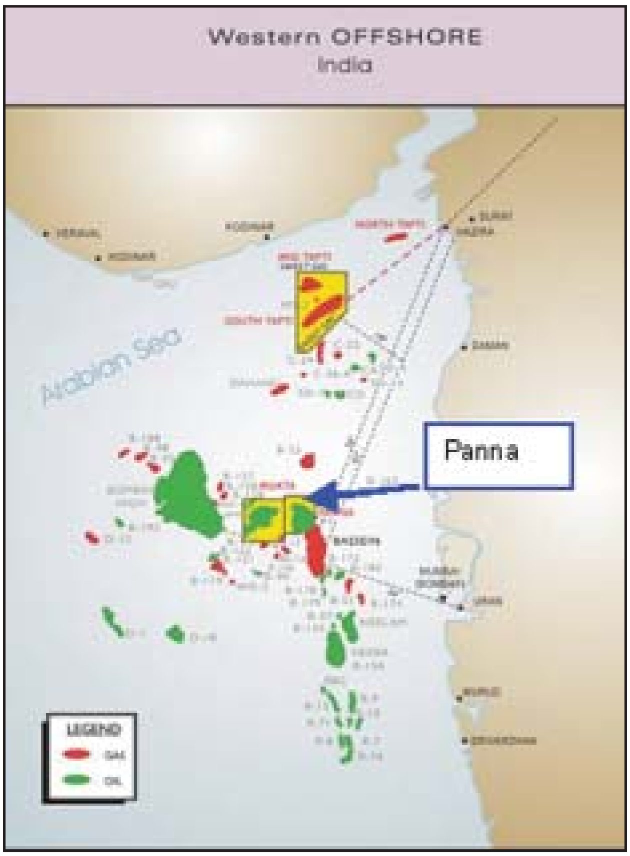

Fig.2: Location Map of Panna Field

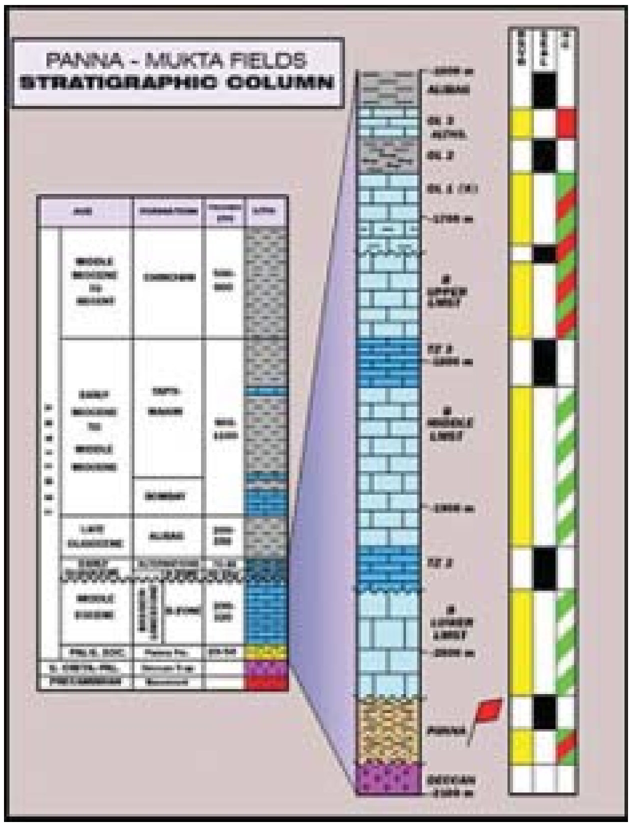

Fig.3: Generalised Stratigraphy of Panna Field

Fig.4: Map showing OWC and wells exisitng before 2002 in Panna Field.

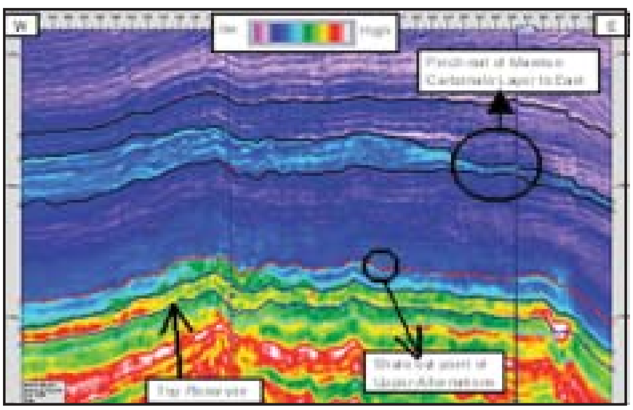

Fig.5: East-West Acoustic Impedance cross section showing lateral velocity variations

towards east and Alternations (Carbonate + Shale) of Oligocene age which shales out towards eastern part of the field. Apart from these two important factors contributing to the obvious velocity variations, the subtle lateral variations within carbonates overlying the reservoir (seen by change in colour laterally) is another factor which results in rapid change of velocities in wells located within few hundreds of meters.

The Panna Field is a mature field (with 20 years of production) and has several wells (>80) within the field and most of them are deviated/horizontal. Even though a depth map on top of reservoir can be obtained by gridding the well markers, it would be a mathematical surface and would not honor geological factors inferred from seismic data.

Results

The choice was to use either layer cake model wherein seismic layer interval velocities at wells are regressed with interval AI or regress average velocity from SRD (seismic reference datum) to target horizon with Average AI calculated from SRD/shallowest horizon to the target horizon. Based on data analysis, use of average velocity and average AI method gave better results in Panna and was able to remove the bias due to pick errors of intermediate time horizons.

For the purpose of this paper we shall discuss the method and results with regard to depth conversion on top of main reservoir in Panna (Bassein B).

Figure-6 shows the spread of the existing vertical wells (10 in number) within the Panna field and which are used as input to define the regression. Most of these vertical wells were used as input to seismic inversion. Figure-7

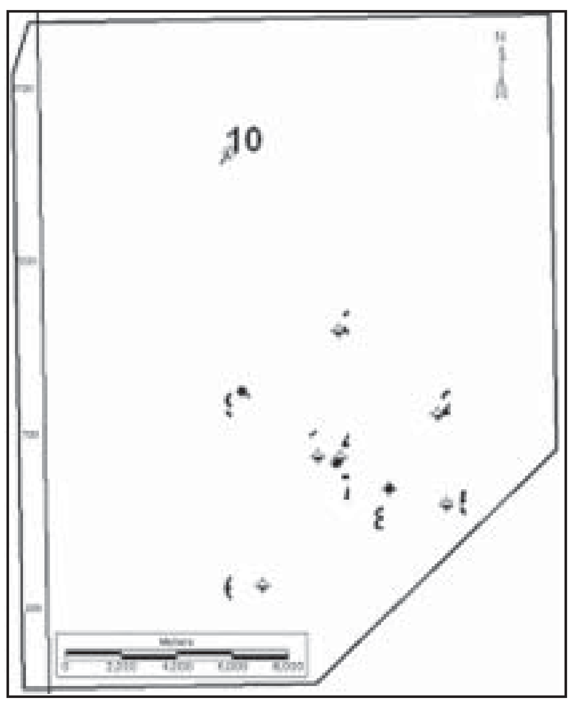

Fig.6: Spread of Vertical/Pilot wells in the Panna Field

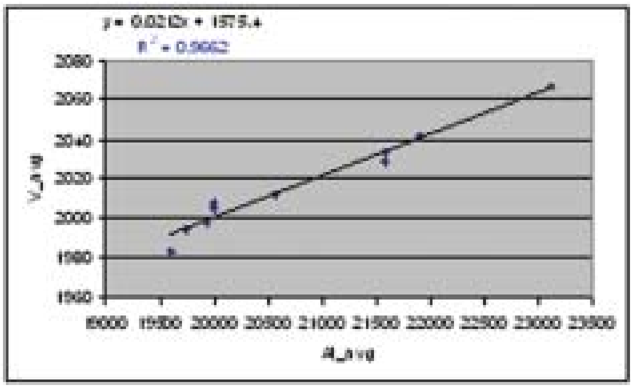

Fig.7: Goodness of Trend Fit between Vavg and AIavg at Vertical/Pilot well locations

shows the goodness of fit between average velocity and average AI values at these wells.

The regressed straight-line equation was used to calculate velocity over the entire field using smoothed AI grid (Figure-8) as input. This velocity volume was used to depth convert the time grid (Figure-9) at the top of the reservoir.

Table-1 lists the errors between actual and predicted depths on top of reservoir in the ten wells used as input in the model.

Figure-10 (error grid map) shows the distribution of errors (predicted depths minus actual depths encountered at each well location) over the entire field. As can be seen, the separation of positive and negative errors is quite clear and this helps in getting an understanding on kind of errors the future wells would have when prognosis is done using this approach.

Figure-11 shows the statistics of errors, which indicates that if depth conversion was done using AI Volume

Table-1: Errors in input wells

Well No	Error in m
1	-4.98
2	-7.39
3	0.51
4	4.15
5	-0.94
6	1.31
7	6.65
8	0.19
9	-0.56
10	1.04

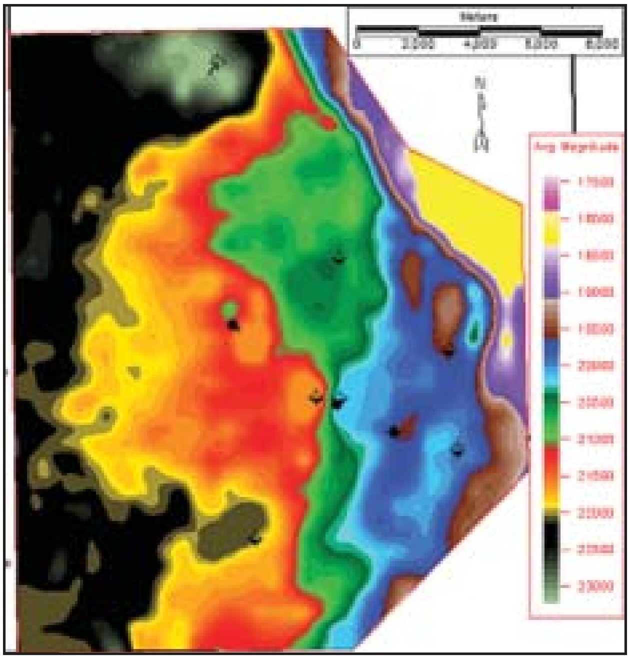

Fig. 8: Smoothed Average AI grid on top of reservoir

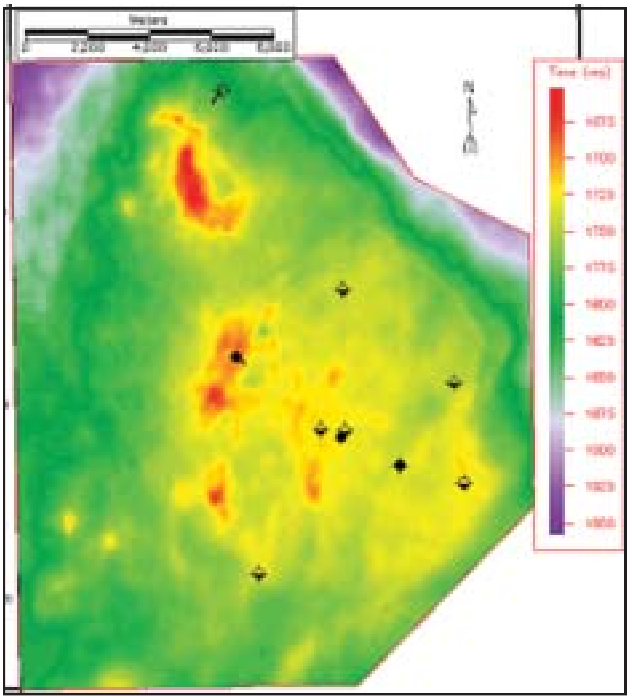

Fig. 9: Two way Time Structure map on top of reservoir

and Velocity information at these 10 well locations even before first development well was drilled in the field, the prognoses to top reservoir in all the wells drilled subsequently would have been as below:

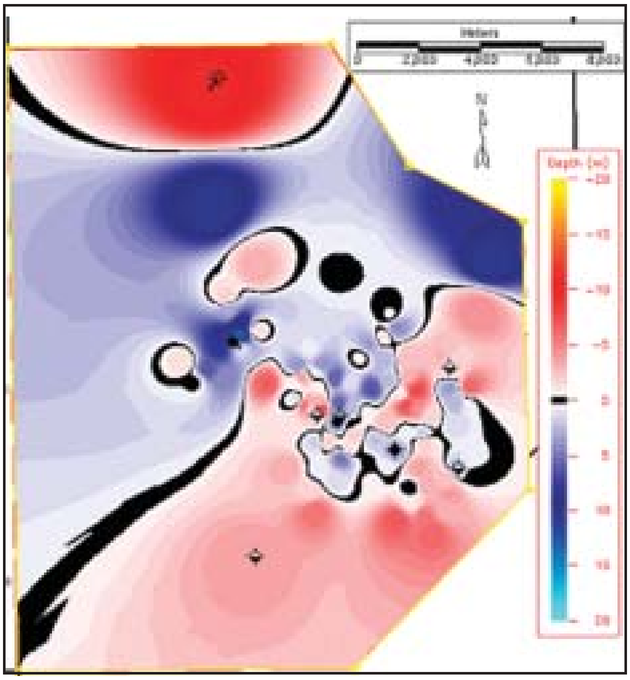

Fig.10: Error Grid on top of reservoir created using variogram analysis. All the wells existing in the field are used.

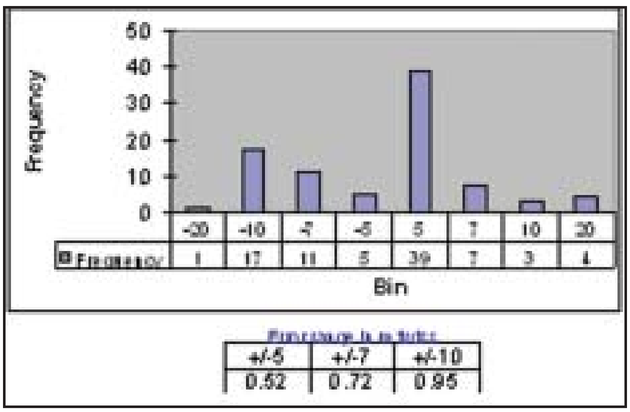

Fig.11: Histogram showing the errors in prognoses for all wells in the field

95% of wells would have seen +/- 10 m error
72% of wells would have seen +/- 7 m error
52% of wells would have seen +/- 5 m error

The next step after creating the depth map is to correct it for the errors recognised in the drilled wells and add the error grid to the computed depth map. There are several methods of error gridding in the form of convergent gridding to geostatistical methods and the suitable method is always the discretion of user based on the knowledge of the area. In Panna, as the error distribution is good in terms of positive and negative areas, geostatistical guided mapping using variogram analysis along with inverse distance algorithm was used to create error grid.

Conclusions

Utilisation of an AI volume in depth conversion has given good results and can be used as an additional tool for depth conversion in other fields alongside already existing depth conversion techniques. The advantage of the approach is in its treatment to lateral velocity variations in a quantitative manner.

It is desirable to have the inversion volume below the shallowest seismic reflector. Quality of inversion and geology of the area determines the success of the approach.

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