Multiple horizons mapping: A better approach for maximizing the value of seismic data

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Abstract

Conventional interpretation workflows today require a limited number of key horizons to be mapped to construct generalized geologic models. The result is that gigabytes of data are often reduced to just a few kilobytes of interpreted data on which key economic decisions are made. An improvement in interpretation can be achieved by greatly increasing the number of mapped horizons. However one of the biggest benefits of having a dense set of horizons is related low frequency model building that can improves the quality of seismic inversion for better reservoir characterization and enhances the accuracy of imaging the reservoir geometry along with proper facis distribution. The dense set of auto-tracked correlated horizons from the dip-steered volume is called a Horizon Cube. Each horizon in the Horizon Cube represents a relative geologic time line.

This paper illustrates the results after application of dense set of horizons tracked from dip-steering cube for different seismic data sets pertain to offshore area. The first example demonstrates the enhancement of imaging of reservoir geometry to extract more information about reservoir from seismic and other two examples reflects the improvement of the accuracy of seismic inversion for better reservoir characterization.

Introduction

One of the single biggest challenges in seismic interpretation today is maximizing the value of geological data. While seismic interpretation technologies have improved dramatically over the last few years in their ability to predict rock type and properties along with fluid types (oil, gas, water) and develop geologically consistent 3D representations of the subsurface, too often operators remain dependent on highly generalized geological models as an input into their economic decision-making.

One of the key reasons for the limitations of a conventional workflow is that only a few key horizons are mapped. To meet these challenges an approach has implemented for increasing the number and density of mapped horizons for maximizing value from existing seismic data.

HorizonCube - a volume containing a dense set of 3D correlated stratigraphic surfaces. With automated horizon tracking tools, it is possible to extract much more geology from the seismic data. With a dense set of auto-tracked horizons we can see more geology by slicing through the data in a geologically sound way.

Seismic inversion, a geophysical tool for estimating elastic interval properties from seismic data, has become a bridge linking of geology, seismology, well-logs and rock physics. The quality of seismic inversion is depends on geological consistency of the initial low frequency model. Likewise, it is suggested that more horizons should be used in building low-frequency models, and that the additional horizons containing local seismic dip information should be auto-tracked from a steering-cube. In general, it is hypothesized that in many geologic settings the following statement is true: "the higher the number of horizons used to construct the low frequency model, the higher the accuracy of the inverted results."

One example in this paper describes the application of dense set of horizons for better understanding of reservoir geometry and another two examples illustrate a comparison of the final inversion result using dense horizons from data-driven HorizonCube and conventional approach during low frequency model building that is supplied as input to the inversion algorithm. The examples also show that this accuracy is critical for quantitative interpretation of lithology and fluid content from seismic data. For all three examples the seismic data is from different offshore area.

Methodology

Fig-1 schematically depicts the workflow. The methods are divided into three stages. In the first stage a steering cube of dip of the seismic events along inline and cross line direction at every sample point is created from the

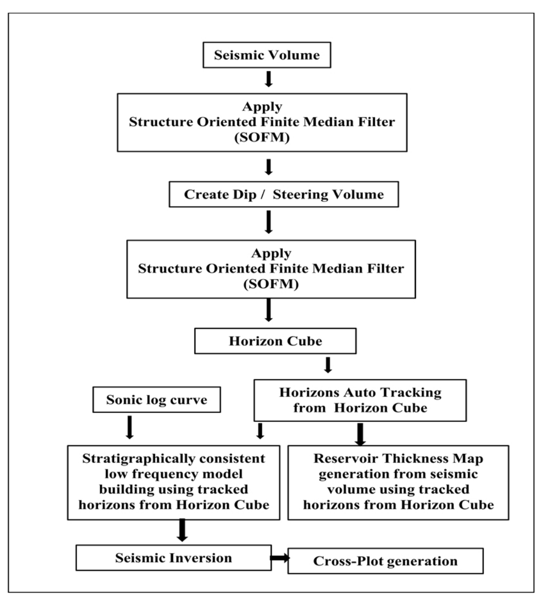


Fig-1: Workflow of adopted Methodology

seismic amplitude volume. In the second stage multiple numbers of horizons are mapped through auto-tracking for generating horizon cube and in third stage using multiple auto tracked horizons, the reservoir thickness maps generation, stratigraphically consistent low frequency model building and seismic inversion are carried out.

Creating Dip Steering Cube

Conventional seismic attributes are calculated in a window without any geological information. Dip-steered seismic attributes overcome such issues by calculating seismic attributes along the dips. It is a technique that extracts dip and azimuth information from seismic by estimating the apparent reflector dip of individual reflectors along seismic line. Dips can be calculated based on Fourier-Radon transforms algorithms that compute dips from the gradient of the instantaneous phase.

Creating a HorizonCube

The approach currently being adopted for generating the horizon cube requires three basic inputs: (i) Few mapped horizons and (ii) the dip steering volume. A special auto-tracker tracks the dip-steering to generate horizons that are typically separated by one sample at the starting position (Fig: 2). Typically a three-dimensional median filter is used to smooth the steering cube that reduces the impact of random noise and enables the user to control the detail that needs to be captured by the horizon tracker. Another advantage is that (smoothed) dip fields are more continuous than amplitude fields. Conventional autotrackers that pick amplitudes and/ or trace similarities stop when the constraints are no longer satisfied. This leads to a set of patchy horizons rather than a set of continuous, chronologically consistent horizons as needed for horizon cube applications.

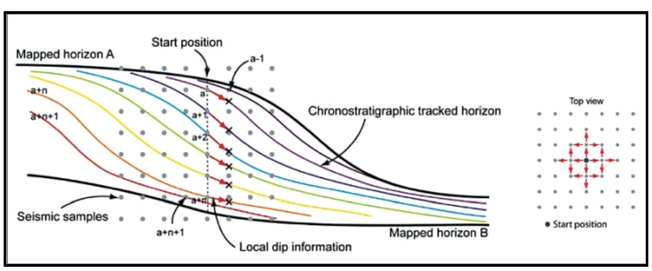


Fig-2: Principle of data-driven tracking of the Horizon Cube using a dip field extracted from the seismic reflectors

Creating Low Frequency Model Building and Seismic Inversion

Once the HorizonCube has been established, a background low frequency model typically contains frequencies in the 0 – 15Hz range can be created. This is a straight forward process, where well properties are now interpolated with accurate structural control. In principle, any lateral interpolation algorithm like inverse distance may be used. The main geologic input in the model building is supplied in the form of seismic horizons to guide the interpolation algorithm. Two separate models using conventional few mapped horizons and dense sets of horizons may be built. After interpolation and manual editing, a low-pass frequency filter is applied to the background model. After this filter, the model contains only information about the low-frequency trends not available in the seismic data. After seismic inversion, this low-frequency trend is added to the seismic inversion result in order to arrive at an absolute or broadband seismic inversion result. These examples will illustrate the increased accuracy of the final inversion result using a data-driven HorizonCube.

Example-1

This example illustrates a clear image of reservoir geometries and facies distribution within the reef core body after application of Horizon Cube. Seismic data is used for this application from a complex reefal and limestone build-up pertain to offshore block. Automated tracking of chrono-stratigraphic unit boundaries is not possible by using conventional tracking methods due to poor quality of 3D seismic data. Amplitude and phase responses are too indistinct for the tracker to trace for any distance in a consistent manner.

It proved feasible, however, to track the dip-field and thus to create a dense set of auto-tracked horizons (Fig-3). These are used to produce a suit of seismic-based maps of depositional cycles and system tracts reflecting the reef build up accretion.

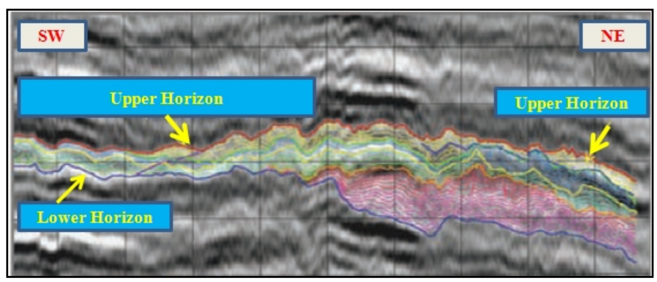


Fig-3 : Seismic section showing auto-tracked (chron-ostratigraphic) horizons from the HorizonCube

Results:

The reservoir thickness maps (Fig-4) generated using auto-tracked dense sets of horizons from dip steered volume certainly enables to extract more geological information from seismic data. It also helps in better imaging of reservoir geometry with clear facis distribution along with details mapping of complex reef reservoir unit.

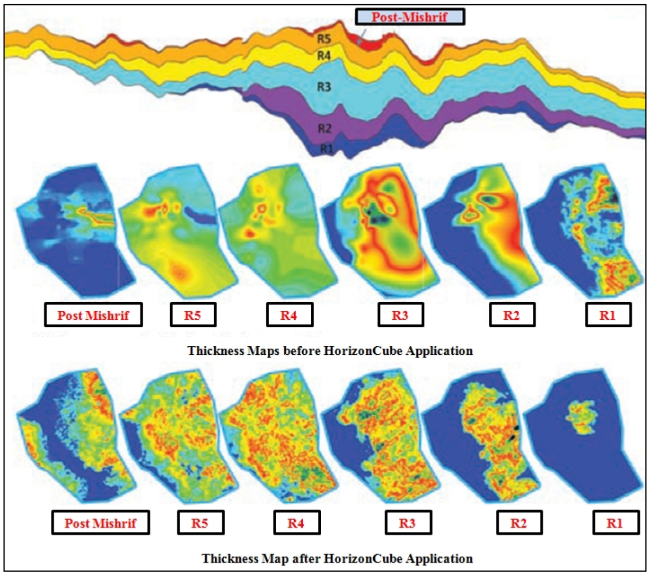


Fig-4: Thickness maps of depositional sequences before and after application of the HorizonCube

Example-2

In this study a target zone (Fig-5) of seismic data pertain to offshore block, is inverted to absolute acoustic impedance using two different low frequency models. Both the models are constructed by using available three wells but in run No.1 the model is constructed in the conventional manner by using only two mapped seismic horizons to guide the interpolation of acoustic impedance well logs. In run No. 2 nineteen additional horizons are used to guide the interpolation algorithm in the construction of the low frequency model. The additional stratigraphi horizons are auto-tracked by a 3D auto-tracker that tracks hundreds of surfaces simultaneously in pre-calculated steering-cube.

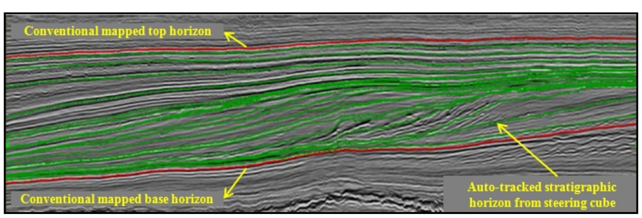


Fig-5: Showing the target interval for the inversion

In Run-1low frequency model building using only by two (top / base) mapped horizons (red surfaces) and in Run 2 by two mapped horizons (red) and 19 additional horizons (green) that were auto-tracked from pre-calculated dip-steering volume subsequently seismic acoustic inversion are carried in target zone

Result & discussion

Low frequency model is overlaid with seismic and as expected the model with 21 horizons much better follows the seismic events (Fig: 6).

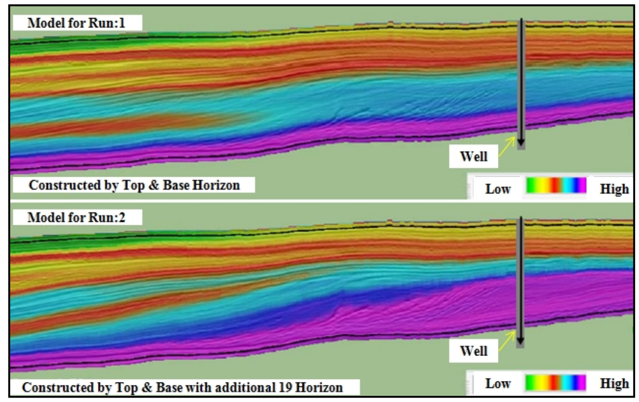


Fig -6**:** Low frequency models of 2 horizons (above) & 21 Horizons (below) overlying the seismic data

In Fig -7 it is certainly reflected the inverted acoustic impedance results obtained in run No. 2 (21 horizons) follow the seismic events much more closely than the inverted results obtained in run No. 1 (2 horizons).

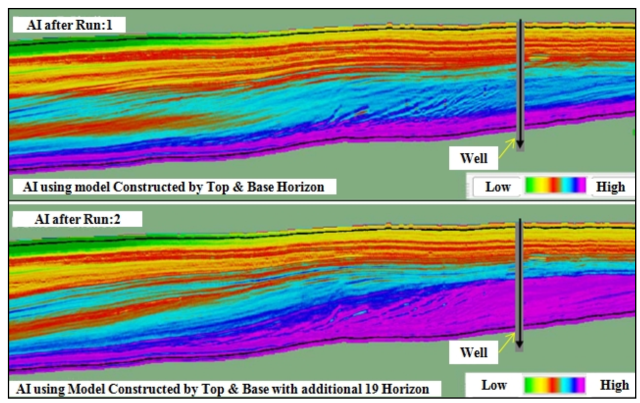
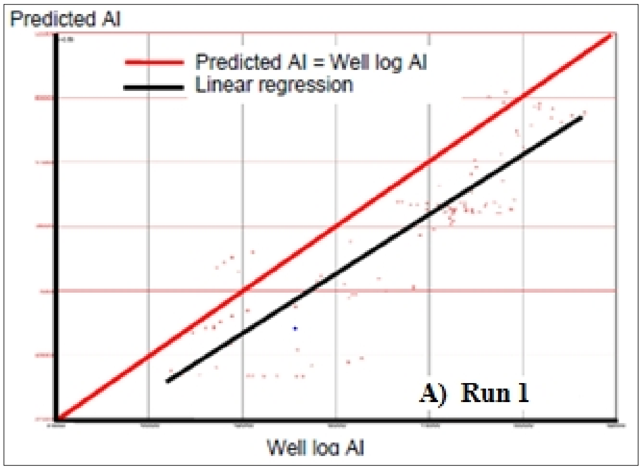


Fig-7: Acoustic impedance inversion results with Run 1(2 horizons) and Run 2 (21 horizons).

A cross-plot of the inverted acoustic impedance versus the well log acoustic impedance at the blind well location is given in Fig-8. It shows that run 1 (2 horizons) under-predicts the actual impedances by approx. 4%. In run 2 the almost correct trend is predicted.

The red line is the correct answer and the black line is the linear regression through the predicted values. The study clearly demonstrates the impact of the low frequency model on the final outcome of an absolute seismic inversion result. The inversion result obtained with a detailed low frequency model that is constructed by using increased number of auto-tracked horizons from steering cube is clearly more accurate than the result obtained with the coarser input model that is constructed by using conventionally mapped top and base horizon.



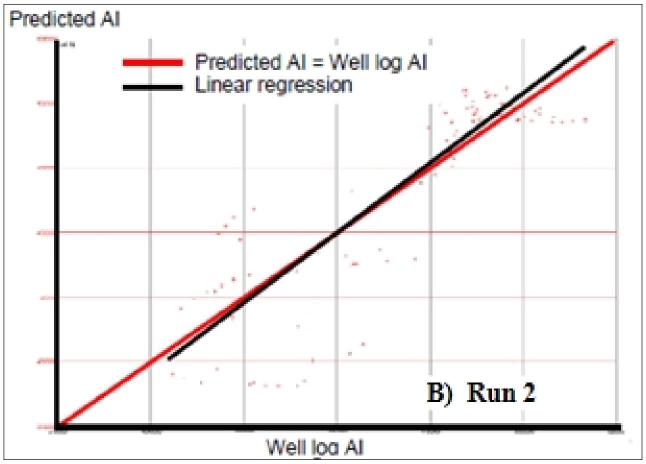


Fig-8: Cross-plots of inverted AI vs. well log (4ms) AI. (A) Run 1 (2 horizons) & (B) Run 2 (21 horizons)

Example-3

In this study, it shows an example of how the application of dense mapped horizon in low frequency model building can improve the final results of Pre-Stack Seismic Inversion which is carried out in a target zone of an offshore seismic data. Fig-9 shows the stacked seismic section from the prestack data used as input to Pre-Stack inversion.

The stacked data were used to derive the HorizonCube. The N1 and N2 reservoirs are the target sandstones under investigation where one well had been drilled.

The first task was to improve the quality of the seismic information through the preconditioning of the seismic data. Secondly, horizon mapping was used to extrapolate the P-impedance and S-impedance logs to create a stratigraphically consistent low-frequency model which incorporates the inversion workflow.

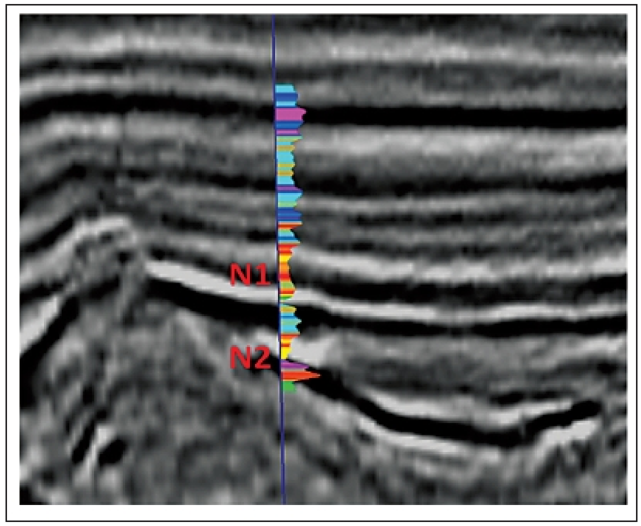


Fig-9**:** A seismic section where inversion was applied (N1 and N2 represents the target sandstones under investigation)

Result & discussion

Fig-10 compares the low-frequency model of P-impedance (left) with two horizon (right) more dense horizon which shows greater consistency with the geology.

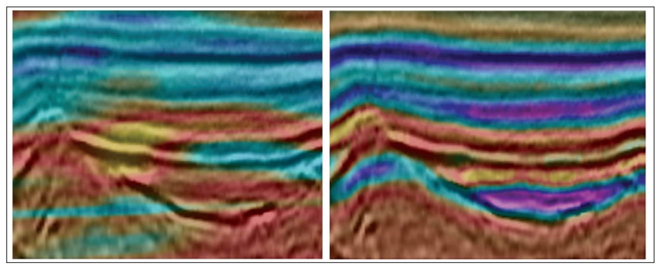


Fig-10: IP background model before (left) and after (right) HorizonCube,

Comparing the results between the inversion, it is clearly seen the benefits of incorporating the horizon mapping into the inversion workflow. It should be noted that, with the increased resolution obtained from the inversion, it was possible to correctly map the reservoir thickness and its lateral extension. The improvement of the correlation coefficient between well logs and the inversion results (from the initial inversion to the final deliverable)—provided the confidence to proceed in generating fluid indicators (Fig-11).

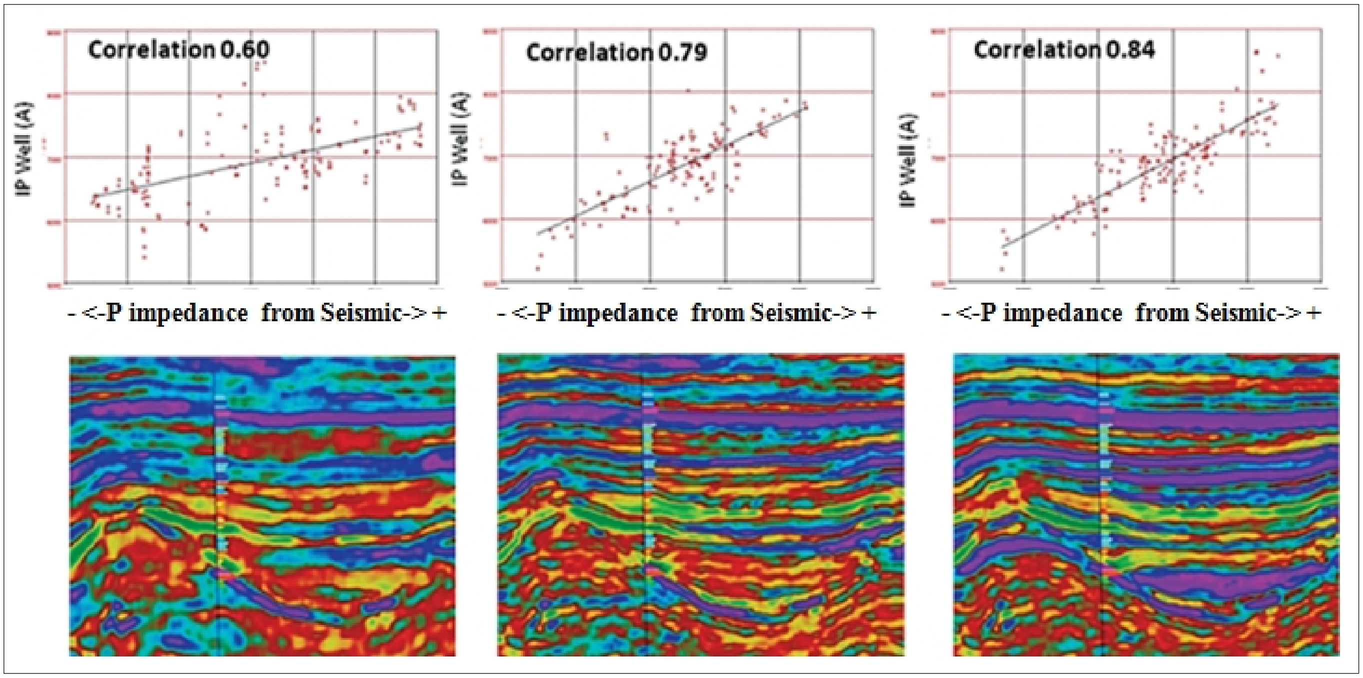


Fig-11: IP inversion results from the initial inversion to the final result. (left to right) P-impedance obtained from prestack data and original background model; P-impedance from preconditioned data and original background model; and P-impedance with preconditioned data and the HorizonCube-derived background model.

A volume of IP and IS is derived enabling the illumination of both levels of the reservoir. The arrows in Fig-12 indicate where the fluid indicator dims, suggesting the limits of the oil-saturated sands.

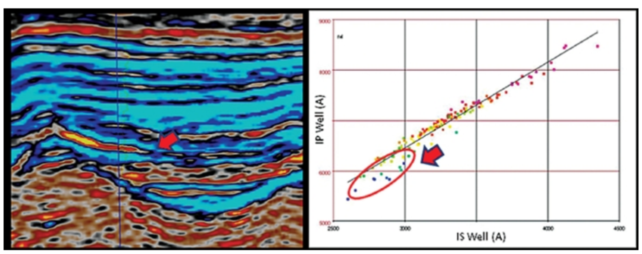


Fig-12: IP-IS fluid indicator associated with the oil sands indicated in the IP × IS crossplot. The red arrow indicates the possible oil-water contact

Conclusion

The three examples discussed in this paper show that a dense set of horizons enables to extract more reservoir information from the seismic data by improved reservoir facies mapping and rock property estimation. In the first example the dip-steered auto-tracker enabled detailed mapping of the complex reef reservoir units. In the other two examples the dense set of horizons auto-tracked from dip steering cube helped to build a stratigraphiclly consistent low frequency model for improving on the final outcome of an absolute seismic inversion result.

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Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

References

OpendTect manual for Dip-Steering and SSIS (Sequence Stratigraphic Interpretation System)

Francis, A., 2006a. Understanding stochastic inversion: Part 1. First Break, Vo. 24, Nov. 2006, 99-77.

De Bruin, G., H. Ligtenberg, N. Hemstra, and K. Tingdahl, 2006, Synchronized sequence stratigraphic interpretation in the depositional and chrono-stratigraphic (Wheeler transformed) domain: EAGE Research Workshop.