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Seismic Correlations of Well Markers in Difficult Settings - An Example from the Nelson Field - Forties Sandstones

F. Qayyum (dGB Earth Sciences), N. Sakuyama (Idemitsu Petroleum UK), V. Romanova (dGB Earth Sciences), A. Huck (dGB Earth Sciences), P.F.M. de Groot* (dGB Earth Sciences)

Summary

In settings characterized by erosional features and sediment infill, mapping unconformities, or sequence boundaries at intra-reservoir levels is the key to building accurate reservoir models. In many such cases, unconformities can be picked reliably in wells. However, correlating these markers from well-to-well on seismic data is challenging. Conventional horizon auto-trackers cannot be used because the seismic response along unconformable events varies laterally. In some cases unconformities can be drawn manually but this is a time-consuming task that, at best, generates inaccurate surfaces. As the complexity of reservoir architecture increases manual drawing becomes more challenging and practically impossible.

In this paper we present a study performed on the Nelson Field as an example of a new method for correlating wells at intra-reservoir levels on seismic data. We use an inversion-based algorithm to create a dense set of horizons that fits exactly at important well markers. The method consists of two steps:

1. With the help of an “unconformity tracker” a set of intra-reservoir framework horizons are produced, which fully honour the well markers.
2. Using a similar inversion-based algorithm a dense set of horizons is created in between the framework horizons.



Introduction

In heterogeneous deep-water turbidite sediments, difficulties arise when using seismic data for intra-reservoir scale correlation. As a result, intra-reservoir surfaces in geologic models of hydrocarbon reservoirs in such settings are often based only on well-log correlations and are gridded without honouring seismic reflectors. Since multi-million dollar field development plans rely on these models, this may result in sub-optimal economic decisions.

In this paper we present a study performed on the Nelson Field as an example of a new method for correlating wells at intra-reservoir levels on seismic data. We use an inversion-based algorithm to create a dense set of horizons that fits exactly at important well markers. The method consists of two steps:

1. With the help of an “unconformity tracker” a set of intra-reservoir framework horizons are produced, which fully honour the well markers.
2. Using a similar inversion-based algorithm a dense set of horizons is created in between the framework horizons.

Method and Theory

In settings characterized by erosional features and sediment infill, mapping unconformities, or sequence boundaries at intra-reservoir levels is the key to building accurate reservoir models. In many such cases, unconformities can be picked reliably in wells. However, correlating these markers from well-to-well on seismic data is challenging. Conventional horizon auto-trackers cannot be used because the seismic response along unconformable events varies laterally. In some cases unconformities can be drawn manually but this is a time-consuming task that, at best, generates inaccurate surfaces. As the complexity of reservoir architecture increases manual drawing becomes more challenging and practically impossible.

The method used in this paper does not rely on tracking amplitudes, or similarities. Instead we use a constrained inversion-based algorithm that aims to flatten the seismic dip field. (Wu and Hale, 2014).

Constraints for the unconformity tracker are given in the form of interpreted positions picked along the event. The set of interpreted positions can consist of any combination of tied well markers and manually- interpreted points. The tracker employs a radial basis interpolation algorithm to create an initial surface through these constraint points. Next the surface between the constraint points is warped such that the difference between surface dip and seismic dip is minimized. In this way a set of framework horizons is generated that tie exactly at the well locations and that follow the seismic reflection patterns in between. Note that this tracker is not limited to tracking unconformities. This is a general-purpose correlation tool that can equally well be used to map other seismic events in a fast and efficient manner.

The next step in the construction of a detailed correlation model is to add more correlated events inside the reservoir. Using a similar inversion-based algorithm a dense set of horizons is generated in the intervals bounded by the framework horizons.

Optionally, to optimize results, additional constraints can be fed to the inversion algorithms. A confidence weight volume can be applied to the dip values before inversion. Weights should be high in areas with good reflectors and low in noisy areas or faults. A good weight volume is “planarity”, a measure of how planar the local dip field is (Luo and Hale, 2011). Additionally, mapped fault planes can be added to change the dip field at fault positions leading to better solutions in faulted areas.



Nelson Field

The Nelson field is located on the Forties Montrose High, approx. 180 km east of Aberdeen in 80m of water. The field produces oil and gas from a relatively simple, low relief anticlinal structure with four-way dip closure. Oil production from the Nelson field started in 1994 with an estimated STOIPP at 790 MMBBL. Maximum production rates peaked at 160.000 barrels of oil per day in 1995 but steadily declined. In 2010, production was approx. 20.000 barrels of oil per day (Gill and Shepherd, 2010). The field is at the mid-mature stage. Current management strategy focusses on maintaining and optimising production from the existing well stock through Well Reservoir & Facilities Management. The opportunity for targeting bypassed oil exists (by additional infill drilling) but it comes with considerable risk owing to the maturity of the field and the associated high BS&W production (95%). One method to help de-risking these targets could be from an enhanced understanding of the reservoir which would require an increasingly detailed reservoir description in order to locate opportunities and to help screen them out for their economic viability.

The reservoir interval comprises sandstones of the Paleocene Forties Sandstone Member. The Forties Sandstone Member overlies the Lista Formation in a conformable relationship and is itself overlain by shales of the Sele Formation. The latter forms a seal for the field. Average porosity of the reservoir is 23% and an average permeability is 216mD. Shale intercalations create vertical and lateral permeability barriers (Fig. 1), which resulted in complex sweep patterns and variably sized pockets of by-passed oil.

On seismic data Top Reservoir (Base Sele) and Base reservoir (Top Chalk) are mapped with confidence but confidently mapping at intra-reservoir scale levels has proved to be challenging. The stratigraphic framework of the Forties Sandstone Member consists of 4th order sequences labelled as T65, T70, T75 and T80, which can be picked and correlated on well data.

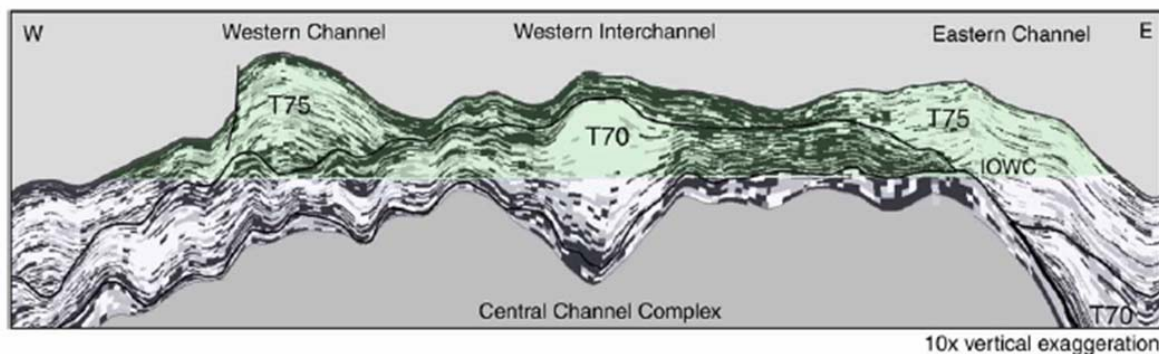


Figure 1 East-West cross-section through the Nelson field (from Gill and Shepherd 2010).

This Study

The study aimed to prove that seismic data can be used for well-to-well correlations at intra-reservoir scale level in this complex, heterogeneous setting. A secondary objective was to extract lithological information from the new correlation grids. These results could be used subsequently to update the static and dynamic models of the field. However, this step was beyond the scope of the pilot study.

For the study 11 wells out of a total of 131 boreholes were used. The following well markers were picked: Top Balder, Sele, Forties, T80MFS, T75MFS, T70MFS, T65MFS and Top Chalk. The 3D seismic data was a full stack PSDM processed volume. Top Balder, Sele, T80 and Top Chalk horizons are reliable seismic events that were available at the start of the project. Other intra-reservoir grids were discarded as these were based on well correlations only and do not necessarily match seismic reflection patterns (Fig. 2).

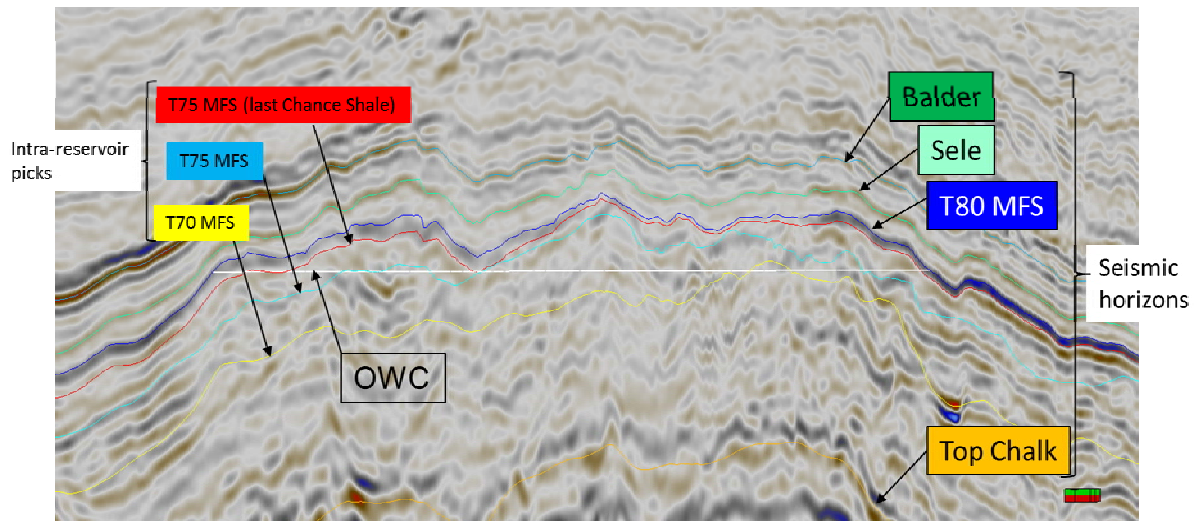


Figure 2 East-West seismic transect through the Nelson field. Top Balder, Top Sele, T80 MFS (top reservoir) and Top Chalk are reliable seismic picks. However, Intra-reservoir picks are well based picks and do not necessarily honor seismic reflectors.

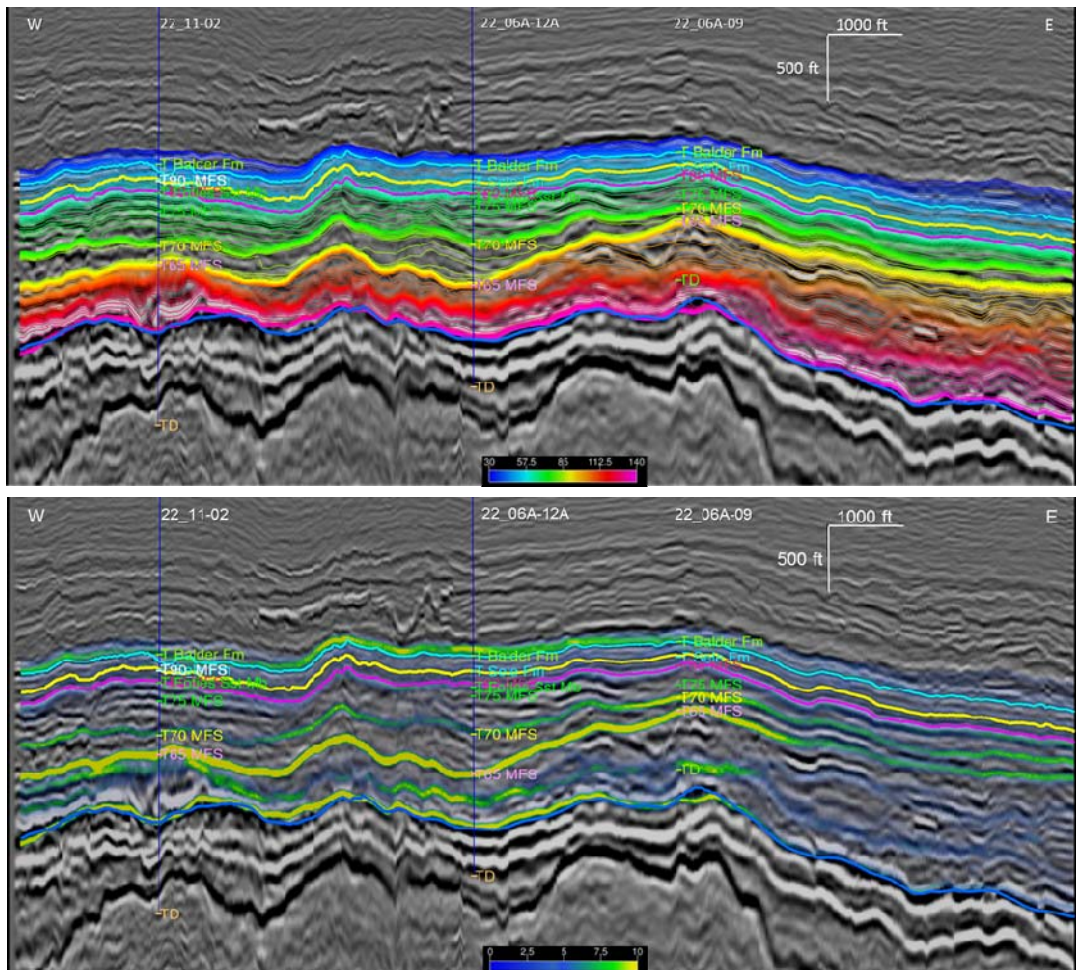


Figure 3 East-West seismic transect through the Nelson field: Top HorizonCube; Bottom HorizonCube Density attribute reveals possible permeability barriers (yellow).

After QC-ing the well-ties, the unconformity tracker was used to create four new intra-reservoir horizons. The new framework horizons tied exactly at the wells. Where possible, the well constraint set was appended with a few manually picked locations. Next, a HorizonCube, constrained by the set of framework horizons, was created in the interval between Top Balder and Top Chalk (Fig. 3 top).

The dense set of horizons enabled the extraction of more geologic information from the seismic data. For example, a “HorizonCube Density” attribute was computed from the dense set. This attribute returns, in a sliding window, the number of horizons per vertical interval. High density values are typically encountered along unconformities and condensed sections (Fig. 3 bottom). The attribute is thus inversely proportional to sedimentation rates. In the Nelson Field, this attribute could indicate the presence of vertical permeability barriers.

Another way to extract information from the dense set of horizons is by computing isochron maps between packages of interest (Fig. 4). Thickness variations reveal the history of the sedimentation process and may indicate the presence of un-swept volumes.

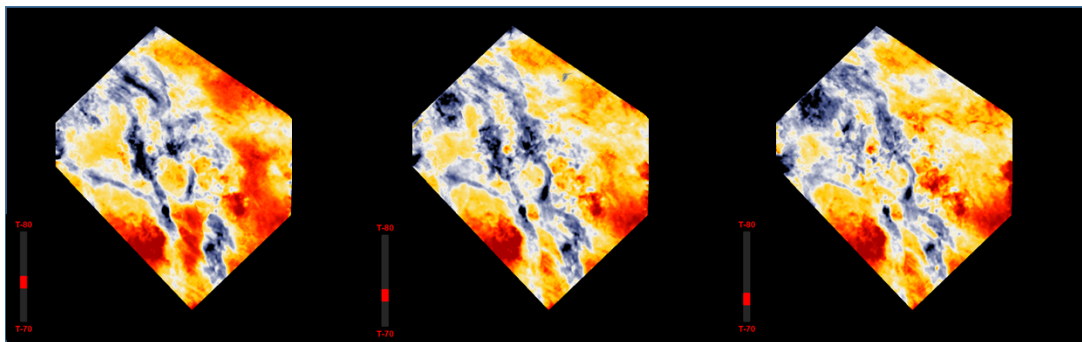


Figure 4 Isochron maps between packages bounded by HorizonCube events reveal the evolution of sub-marine channel systems.

Conclusions

The inversion-based solution for correlating wells at intra-reservoir scale levels discussed in this paper optimally integrates well and seismic information. This potentially leads to more accurate field models for complex heterogeneous reservoirs and to better economic field development decisions.

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