# Waveform classification as a pseudo for reservoir thickness

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## SUMMARY

In an incised channel lacustrine shoreface environment the thickness of the incised channels is unknown away from well control. The thickness often varies over short distances and is the predominant control on reservoir quality, as the best reservoir is in the channels and not the shoreface. A common practice in reservoir modelling is to use an empirical relationship between channel thicknesses to derive width ratios. However, this cannot indicate where other channel bodies are in the area of interest. This study created a relationship between waveform classifications and thickness. The absence of an upper peak-trough within the seismic trace was considered to be indicative of where the upper reservoir unit, incised channels, were present. A relationship was defined whereby the more prominent the upper peak-trough, the more shoreface preserved. Using this method, it is proposed that erosion, and subsequent channel fill, controls the presence of the upper peak-trough. Therefore, waveform classification schemes can be used as a probability map in the static model to control the channel thickness and distribution. The resultant models matched thickness of the upper incised channels at the wells and provide realistically geological models which are able to predict thickness away from well control. At the present, work is ongoing to understand what the waveform represents at wells with a poorer match.

**Key words:** lacustrine, incised channels, waveform, classification, thickness

## INTRODUCTION

To prepare for the upcoming drilling campaign in Field A, it is important to define a method of identifying the better quality reservoir. In Field A the better quality reservoir is the channel facies in an incised channel valley. However, this erosive feature has a high degree of lateral heterogeneity. In an incised channel lacustrine shoreface environment the thickness of the incised channels is unknown away from well control. The thickness often varies over short spaces and is the predominant control on reservoir quality i.e. the best reservoir is in the channels and not the shoreface. At drilled locations where the channel thickness is known empirical relationships such as Fielding and Crane (1987) can be used to estimate channel width. However, due to the nature of the channels, predicting channel thickness and width away from well control in incised valley systems is impossible using well data alone.

Waveform classification is a method of seismic geomorphology which can be used to provide a plan view evaluation of groups allocated by their wave shape. In Field A, for traces where the upper peak-trough is missing, or partially present, it is assumed to be a response to the erosion of the shoreface by incisive channels. This allows a plan view to be created whereby areas of higher erosion, i.e. channel dominated, can be identified by their wave shape. The plan view grid can then be used in Petrel to create a probability map for the thickness of the upper and lower reservoir intervals where the upper reservoir interval is channel dominated and the lower reservoir shoreface dominated.

The new thickness model fits well to the conceptual geology in that it looks like an incised system. From the current production in the field it is clear that some wells are in one channel system and others in separate channel system. The new thickness model demonstrates a degree of physical separation between these channels. The general validity of the model therefore is considered to be fit for purpose to use as a guide to future drilling. With the caveat that some wells sit outside the classification and more work on alternative seismic models needs to be done.

## IMPORTANCE OF SEISMIC VOLUME AND INTERPRETATION INPUTS

As a method of seismic geomorphology, waveform classification provides a plan view evaluation of groups allocated by their wave-shape. The workflow of this method is highly dependent on two factors. Firstly, the seismic volume used to generate the waveform classification scheme and secondly, the correctness of the horizon interpretation. The best results are observed when the seismic volume used has the original spatial relationships between traces retained. Applications of F-K, F-XY or spectral enhancements filters, which either distort the spatial relationship or implement trace changes independent of adjacent traces, will introduce changes to the classification scheme. This study uses a raw stack volume without post stack filters, retaining the original amplitude and wave-shape information.

The correctness of horizon interpretation is also important in maintaining integrity within the classification scheme. Should the top or bottom controls of the waveform classification zone, defined by the horizon interpretations, be inaccurate, those inaccuracies will be carried into the classification. An example of this would be seen if the upper horizon deviated laterally from an original peak into an above trough. The classification scheme would incorrectly indicate the section to have an increase in wave-shape of half a wavelet.

The success of the waveform classification workflow hinges on the correctness of the input data, particularly the horizon interpretation and the seismic volume chosen.

## CREATING THE WAVEFORM CLASSIFICATION SCHEME

Waveform classification is a means of grouping seismic traces according to their individual wave-shapes. Automatic seismic classification methods can be useful for discovering or identifying geologically significant trends that may not be visually detected by interpreters within an unaltered seismic volume (Marroquin, 2013). This study uses an unsupervised cluster analysis as the waveform classes are not defined using well data. Within a defined interval, an artificial intelligence process is used to look for recurring patterns of traces and builds a set of model traces representative of the entire dataset (Paradigm, 2014).

In conjunction with the input parameters, the number of classes is an important consideration. An iterative process is used to determine the optimum number of classes. Too many classes is found to introduce noise into the plan-view image. Too few classes makes it difficult for the interpreter to distinguish patterns of consequence as the resultant image is often blocky and lacks detail. It was found that nine classes is optimal for this study.

The waveform classification method has been applied to Field A within the Cooper Basin and targets the main reservoir interval. To maintain the lateral integrity, the interval is defined by the two most consistent reflectors surrounding the reservoir target. Priority was given to reflector uniformity over decreasing the window of investigation. The resulting wavelets range up to one and a half wavelengths long. The waveform classification scheme and corresponding modelled classes are shown in Figure 1.

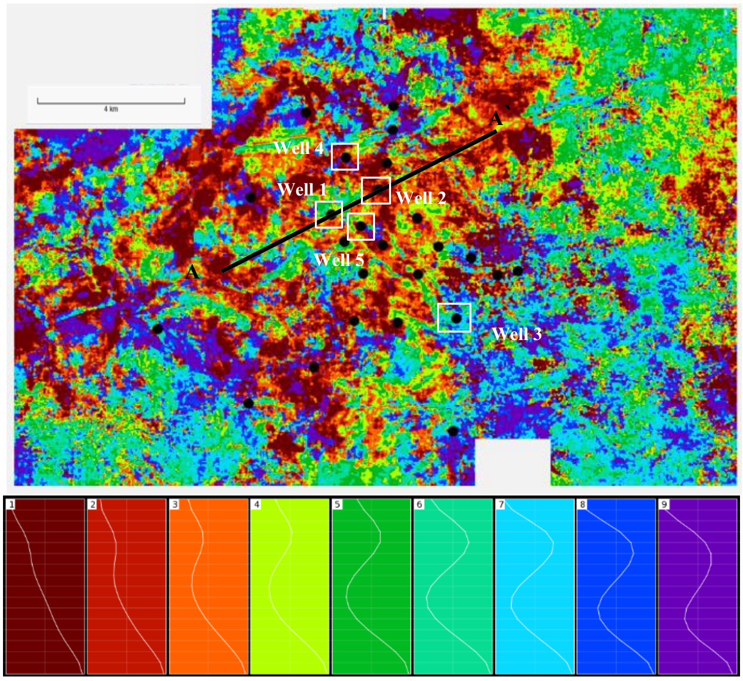


**Figure 1: Waveform classification results with waveform classes. Cross section, Figure 2, location indicated. Wells discussed highlighted in white boxs.**

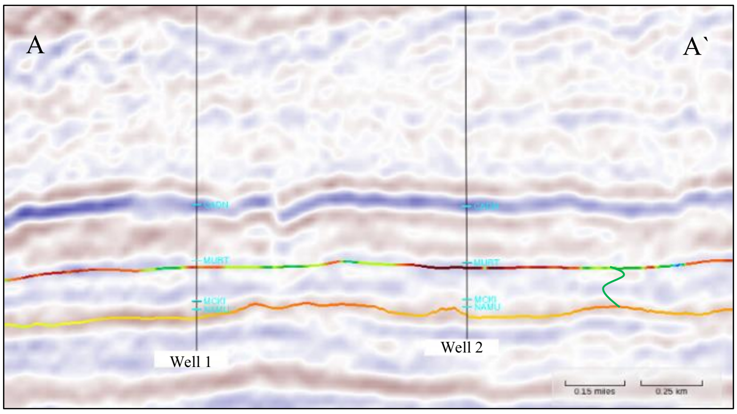


**Figure 2: Seismic section of raw volume from A to A`. Peaks are red, troughs are blue. Upper reflector showing class colours along section. A schematic example of class 5 shows wavelet extraction limits.**

## CONNECTING THE WAVEFORM CLASSIFICATION SCHEME TO FIELD A

Observations of the waveform classifiaction scheme reveal the addition of a peak-trough sequence in some waveform classes. This is clear when comparing Class 1 and Class 9 (shown in maroon and purple, respectively, Figure 1). The changing waveform shape is compared to the well data and knowledge of the depositional system to determine if the classification scheme can be used to infer geological information away from wells.

Lateral trends observed in Figure 1 appear geological and are trending in directions consistant with the current geological understanding of the system. Furthermore, it was found that a good match is derived between the wells containing incised channel sands and the lower classes, that do not have the extra peak-trough. It is then proposed that where incisions occur, layers of sediment are erroded and filled with a more physically consistant material, the channel, and therefore eliminate the extra variations in acoustic impedence which cause the additional peak-trough sequence. This proposition is supported by many well observations.

A seismic cross section, Figure 2, shows the waveform classification scheme with two wells in Field A. The location of the section is indicated between A and A` in Figure 1. The two interpreted picks show the interval used to define the classifiaction. The upper pick is coloured to show the variation in waveform class. Colours used are consistant with the scheme shown in Figure 1.

Both Well 1 and Well 2 sit within the orange-red zones in indicating a low waveform class. This classification is consistant with well logs showing the two wells to have penetrated two separate incised channel systems. Furthermore, production from the channel penetrated by Well 2 is better than that from Well 1, giving confidence to the classification scheme.

While there is a reasonable fit to the wells and the geological understanding of the field, several key wells do not fit the classification scheme. Well 3, indicated in Figure 1, is one example that does not match the classification scheme. This well is classified as Class 7, indicating it is not within an incised valley. However, this is not the case as a thick, incised channel sand is found. To understand these inconsistanies, more work is required to validate the unsupervised classification scheme.

Although a more thourough understanding of the wavefrom classification is nessessary, the observed correlation is certainly strong enough to use the classifiaction scheme as a guide to channel distribution within a model.

## USING WAVEFORM CLASSIFICATION TO BUILD A THICKNESS MODEL

The upper reservoir isochore is difficult to predict away from well control because of the erosive nature of the incised channels across Field A. Although empirical relationships such as Fielding and Crane (1987) could be used to define channel belt widths for given thickness seen in the wells. The presences of other channels away from wells could not be reasonably estimated. Therefore, although a fairly constant isochore from the top porosity to the Maximum Flooding Surface (MFS) was available dividing it into an upper reservoir interval and a lower non-reservoir interval was difficult. However, one of the seismic derived properties waveform classifications offered possibilities to create a pseudo map of the upper and lower reservoir thickness.

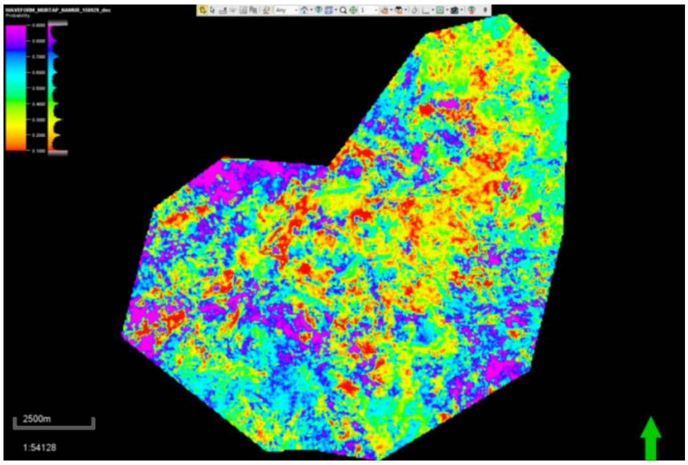


**Figure 3: Thickness probability map derived from waveform classification**

The waveform classification shows that where the upper reservoir channel sands are present the upper peak in the waveform is missing. This is considered to be the result of the erosion from the incised channels. The waveform classification map has values of 1 – 9 with 1 having none of the upper peak present and 9 having the full peak. Therefore, the map of the waveform classification can be used in the surface calculator to generate a probability map of the lower non-reservoir thickness.

The waveform map is divided by 10 so that where the peak is full i.e. maximum lower reservoir preserved the value of 9 would be 0.9, i.e. a 90% probability of lower reservoir. Where the peak is missing the value of 1 would become 0.1, effectively a 10% probability of there being lower non-reservoir. This resulting probability map (see Figure 3) can then be used to multiply the top porosity to MFS isochore, and generate a lower non-reservoir thickness from the waveform. When this lower non-reservoir thickness grid is taken away from the top porosity to MFS isochore, the residual is the upper reservoir thickness.

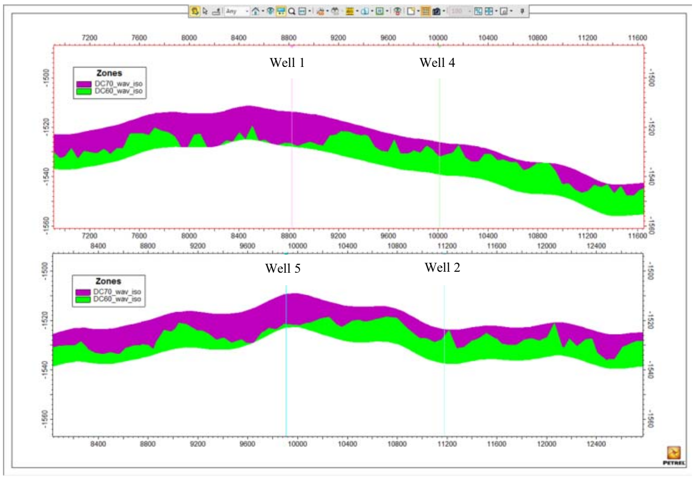


**Figure 4: Thickness sections through model**

The primary inputs to the zone model in the zones process were the isochores made from the waveform classification map and the well tops The results of this approach to the zone modelling has created a more realistic upper reservoir zone model,

It should be noted that the isochores show realistic accommodation space for the previously interpreted channels and fit well with the upper reservoir thicknesses seen in the wells (Figure 4). In addition, the thinning of upper reservoir between the wells 1 and 4 and the same thinning seen between wells 5 and 2 may help to explain the lack of initial communication between these wells, as wells 2 and 4 are interpreted to be in a separate channel to wells 1 and 5. Well locations are provided in Figure 1. This method has provided a container for channel facies in the model which is controlled away from wells by the seismic derived waveform classification.

As noted in the sections on waveform classification, the match to thickness for some wells is sub-optimal. For these wells the model uses well thickness. Work is ongoing to understand this miss-match. A possible explanation is that this reservoir sequence is below seismic resolution and, therefore, other deeper sections of the sediment sequence may be influencing the wave-shape more prominently. If this is the case then the overall drainage pattern for all cycles may be similar and the waveform should be used as a generic indication away from well control, with an uncertainty range.

## CONCLUSIONS

It is possible to use waveform classification as a pseudo for thickness away from well control. In the test field the erosive channels are defined by areas in the waveform where the upper peak-trough is partially or completely missing from the modelled seismic trace. The resultant thickness model fits well with conceptual model and helps to explain the separate channels which are identified from production data. Finding these relationships is particularly important given the difficultly of incised channel predition away from well control. However, not all the wells in the field match the scheme and more work needs to be done in validating the unsupervised waveform classification scheme.

## ACKNOWLEDGMENTS

The authors would like to thank Santos, and their Joint Venture partners, for their permission to publish and present this work.

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