Facilitating Interpretation of Depositional Features in the McMurray Formation through the use of Seismic Multi-Attribute Analysis (MAA) Volumes*

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Abstract

Interpretation of subtle depositional features, like point bar sequences in the McMurray Formation in the Athabasca oil sands region of northeastern Alberta, can be made significantly easier through the use of multi-attribute seismic (MAA) volumes. These volumes approximate well log properties between existing wells from seismic data. MAA volumes have been shown to be useful for identifying sands and shales in the McMurray Formation and we are now using these volumes to facilitate the interpretation of large-scale depositional elements within the McMurray Formation.

Introduction

In oil sands reservoirs, it has been observed that pertinent reservoir properties expressed in well logs, such as lithology, porosity, shale volume and fluid saturation, are strongly related to bulk density (e.g. Gray, 2011; Gray et al., 2006). Bulk density is a rock property that can be measured from oil sands seismic data (e.g. Gray et al., 2006). Seismic multi-attribute analysis (MAA) is a tool used to estimate these reservoir properties from seismic data between existing wells (Hampson et al., 2001) at every sample in the seismic section.

The depositional model for the McMurray Formation used in this area consists of stacked point bar successions (depositional storeys) within an incised valley. Identifying each point bar and the distribution of reservoir facies within it is used to help plan reservoir development. Typically, point bars are described as fining-upward packages. These packages are subtle and are difficult to interpret on the conventional seismic stack through most of the McMurray Formation, with the exception of where gas is present in the upper McMurray. The use of facies, density and Vshale volumes derived from seismic (via MAA) aids in the interpretation of depositional packages within the McMurray Formation by providing information about continuity of point bars and depositional storeys between wells.

Method

The method described here starts by comparing well log reservoir properties, like porosity, lithology, facies and saturation, to well log acoustic properties, i.e. P-wave sonic, S-wave sonic and density logs. If there is a relationship between acoustic properties and other well logs, it is reasonable to use the MAA methodology to predict these well log properties from the seismic data (Hampson et al., 2001). The MAA process outputs three-dimensional volumes (e.g. Gray et al., 2006) that are used in conjunction with the conventional seismic stack to interpret lithology and saturation changes, such as the depositional channel storeys within the McMurray Formation that would be difficult to interpret from the seismic stack alone. Since the seismic data and the well logs measure at different resolutions, the MAA derived from seismic should be checked to ensure that the relationships observed in the well logs are still valid or that a reasonable alternative exists.

Examples

Incorporation of MAA volumes has been used to assist in the interpretation of depositional storeys in the McMurray Formation in two different oil sands projects. In the first example (Figure 1), a density volume generated via the MAA process was used to assist in the interpretation. In the second example (Figure 2), a Vsh volume generated via the MAA process was used to assist in the interpretation.

In the first example (Figure 1), the seismic stack shows clear delineation of shale and sand, particularly in the upper parts of the McMurray Formation. This is likely due to the local presence of gas in the sands within this area and the associated contrast in acoustic properties between the shales and gas-charged sands. However, deeper in the McMurray Formation, the absence of gas makes this delineation more difficult and instead we must rely solely on the different density properties of the sand and shale. Therefore, the colored density volume in the lower part of the Figure 1 displays where the sands are located (Gray, 2011). For example, the base of Storey 3 (blue line below Storey 3) is difficult to interpret from the stack volume, but becomes more clearly defined as a transition from yellow (sand) to green (shale) in the MAA density volume. Furthermore, the sands in Storey 2 are much easier to define laterally. The Storey 2 sand in Well 4 is laterally continuous with the sand in Wells 1, 2, and 3 and extends some distance to the left, while the sand observed in Well 1 terminates just to the right of the well. This latter interpretation is unlikely to be made without the aid of the MAA density volume.

In the second example (Figure 2), the Vshale volume shows a mix of clean and shaley sands in Storeys 3 and 4. The quality of these sands would be difficult to assess from the seismic stack alone. For example, it would be difficult to evaluate the presence of what appears to be a zone of breccia clasts (splotchy brown shales in the orange sands in the Vsh section) between wells 3 and 4 in Storey 4 from the stack data alone. A shallow McMurray channel is clear in both sections (purple label) and both the Vsh volume and Well 4 show it to be filled with shaley sand. The base of Storey 4 (red line) appears to have associated breccia clasts above it (e.g. between wells 3 and 4) but sometimes it is a sand-on-sand contact (e.g. between wells 2 and 3).

An additional benefit in using MAA volumes is improved cross-disciplinary communication. Geologists and geophysicists can now visualize the distribution of geologic properties in 3D space and better interpret depositional storeys within the McMurray Formation.

Conclusions

Predicting rock properties such as Vsh and density between existing wells using multi-attribute analysis (MAA) is proving useful in the interpretation of subtle intra-McMurray geologic features such as channel storeys. These features can be easily identified on MAA volumes. The improved geological interpretation increases the understanding of reservoir property distribution when creating geologic models and development plans.

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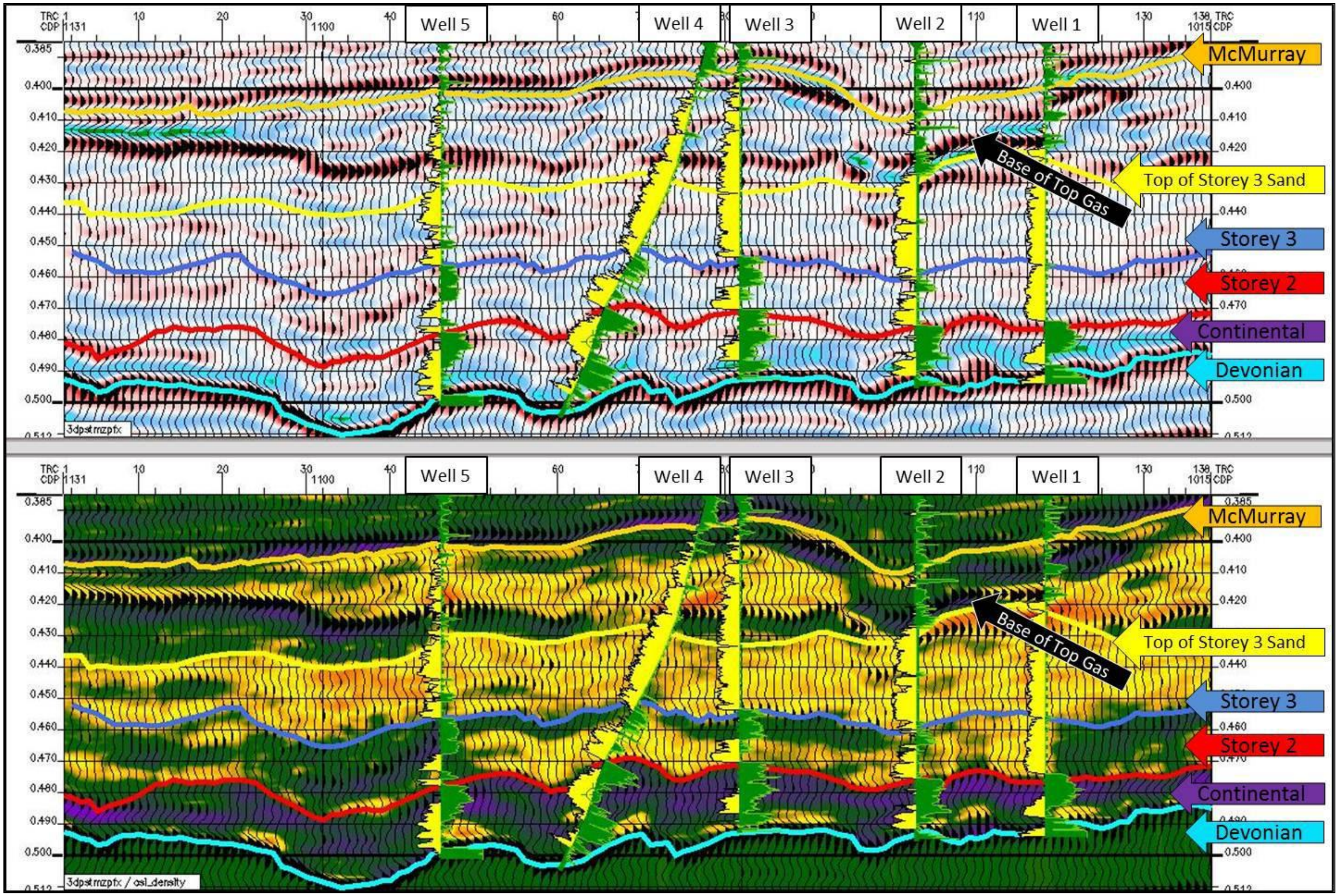

Figure 1. The upper seismic cross section shows the interpretation of depositional storeys overlain on the seismic stack. The McMurray Formation occurs from about 400 to 490ms. The lower seismic cross section shows the same interpretation overlain on a density volume generated by the MAA process, where yellow and orange colours represent sands and green represents shales. This seismic cross section shows that the lowermost sand (455 - 472ms) terminates just to the right of Well 1. In comparison, there is no reason to interpret this termination from the stack alone. The wiggle traces overlain on the density cross section are the stack traces from the upper section for reference. The well logs overlain on the well traces are gamma ray (yellow, left) and density (green, right).

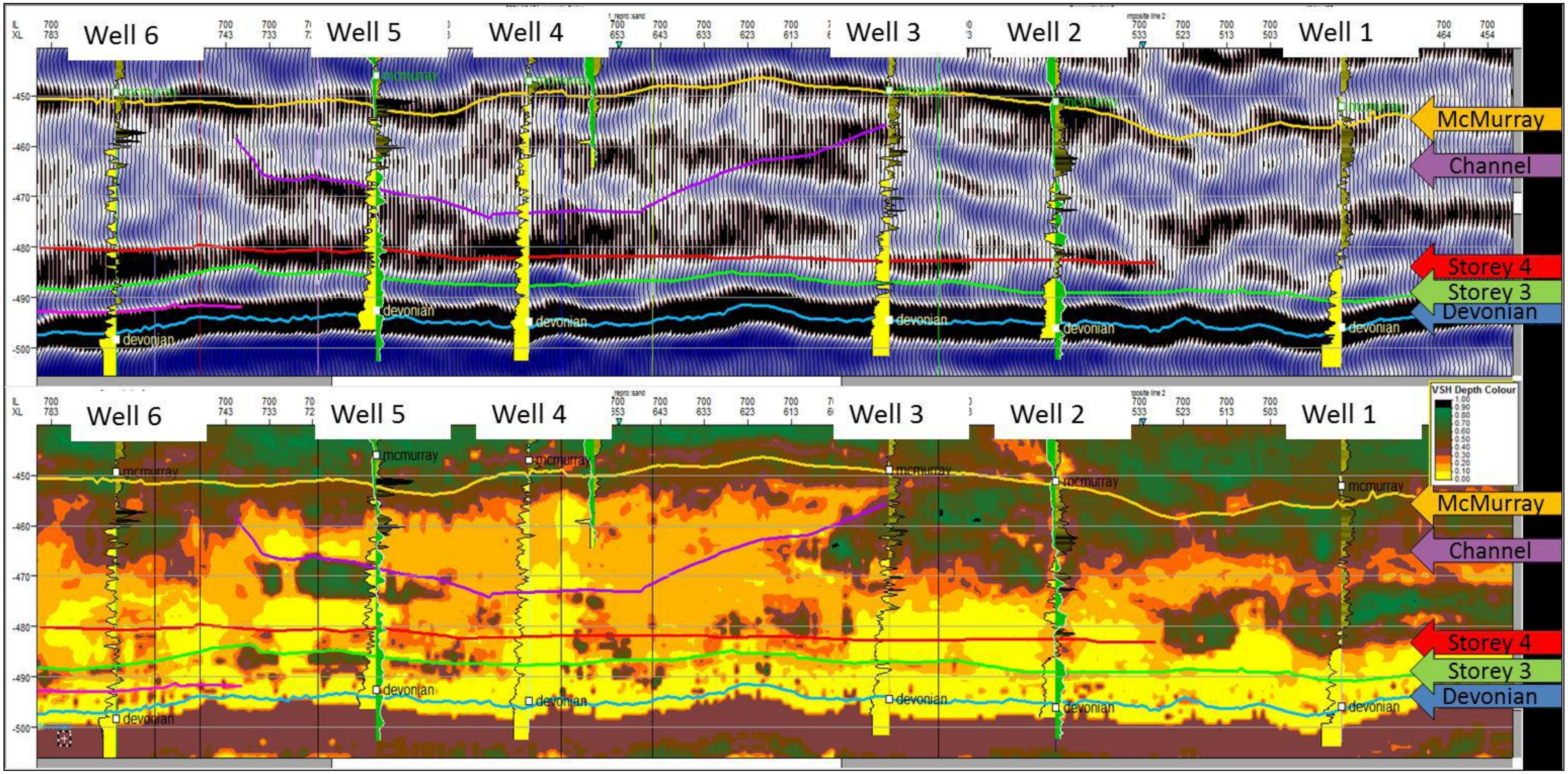

Figure 2. The upper seismic cross section shows a seismic stack overlain by the interpreted depositional storeys within the McMurray Formation. The McMurray Formation occurs from approximately 450 to 490ms. The lower seismic cross section shows the same interpretation overlain on a Vsh volume generated using the MAA process, where yellow and orange colours are sands and green and brown represents are shale. The well logs overlain on the well traces are gamma ray on the left and resistivity on the right of the track. The arrows on the right label the base of the interpreted depositional storeys, which are lines in the section of the same colour.