Mackenzie Delta seismic case study – a reprocessing perspective

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Whenever the geological objectives are not met by the available seismic data processed some years ago, the interpreters like to go back and check the quality of the field data. This is necessitated by the fact that advanced techniques aimed at enhancing the signal-to-noise ratio and frequency of the data available now did not exist then. Sometimes, the data is acquired in different campaigns and this usually results in apparent differences in the quality of the processed seismic data. Integrated interpretation requirements necessitate the use of seismic data of similar quality and so the data require reprocessing. Reprocessing of seismic data carried out using state-of-the-art processing techniques usually show an overall significant improvement in terms of reflection detail and frequency or in specific zones if the reprocessing effort is focused on specific targets. Such reprocessed seismic data are amenable for a more meaningful interpretation.

In keeping with this trend, both 2D surface seismic and borehole seismic data (VSP) from the Mallik area of the North West Territories were picked up for reprocessing. As stated above, the objective was to assess the extent to which the improvement could be brought about and how it could be fruitfully used for interpretation.

Surface seismic data

2D surface seismic data was acquired by Imperial Oil Ltd. in 1970, using DFS III recording system. This 6 fold data had a sample interval of 2 ms and record length 7 seconds, with large group and shot intervals (300 ft and 1200 ft resp.) and with a high cut filter of 62 hz. Looking at the acquisition parameters, any remote idea in our mind to do AVO analysis dried up. However, the data for a 2D profile passing through well 2L-38 was picked up for reprocessing. The earlier processed paper section showed the data to be of poor quality where the reflection detail could hardly be seen. The objective for reprocessing was to see if some of the reflections could be imaged using the processing techniques available in our arsenal, and also to see how well the reflection detail on the profile correlate with the VSP or well synthetics.

The steps in the processing sequence that differed from the earlier sequence adopted for processing the 2D seismic profile were as follows:

1. Refraction statics
2. Surface consistent deconvolution
3. LIFT for noise removal
4. F-X migration

These techniques were probably not available at the time of the original processing. While the other steps are now used routinely, LIFT is a new proprietary technique that is used to attenuate noise and multiples in the seismic data (Choo and Sudhakar, 2003). Signal and noise are first modeled using the available techniques and then the noise component is removed in an adaptive non-linear manner. The methodology assumes importance when amplitude preservation is critical for such applications as AVO inversion, or even for interpretation.

Figure1 shows a set of records before and after LIFT and also gives an idea about the quality of the data. Evidently, some signal can now be seen on the records after LIFT.

The reprocessed section is shown in Figure 2 and may be compared with the earlier processed section in Figure 3. Notice the improvement in the quality of the data. Reflection detail is clearly seen on the reprocessed section.

Borehole data

Well log curves and VSP data were acquired in well 2L-38 by Schlumberger in 1998. The well was drilled to investigate gas hydrates in a collaborative research project between Japan National Oil Company, Japan Petroleum Exploration Company, Geological Survey of Canada and the US Geological Survey.

Figure 4 shows a plot of Vp and Vs curves for this well. The high velocity zones indicate the presence of gas hydrates (Figure 5). These high velocity zones also show up with variable resistivities on a Vp-Vs-Resistivity, 3D cross-plot, the variation in resistivity occurring because of the saturation of the hydrate.

The available VSP data was picked up for reprocessing as the newer methods for VSP wavefield were intended to yield better results. Figure 6 shows the aligned upgoing wavefield and the correlation of this wavefield with well logs and seismic data. The formation tops corresponding to the hydrate zones clearly indicate their seismic reflections which can now be picked up for more detailed analysis.

Free gas is usually associated with the base of the hydrate zones as they provide a seal for such accumulations. The velocity logs in Figure 4 indicate the existence of 1.5 m of free gas. The next logical step was to understand the AVO effect of this zone (Ecker et al 2001), though such a zone would not be detected seismically.

Figure shows the AVO response from the well logs and while reflections are seen for high hydrate concentrations, as expected no reflection is seen associated with the free gas (Figure 7(a)). When the thickness of this gas zone is increased to 20 m, it shows up an AVO effect as seen on the right side (Figure 7(b)).

Conclusions

1. Reprocessing of the seismic profile indicates significant improvement over the earlier processed data.
2. Use of LIFT workflow for wavefield separation yields an upgoing VSP wavefield having more high frequency detail that correlates better with the well logs and seismic.
3. While AVO modeling shows up good response for the existence of free gas below the hydrate zone, AVO analysis is difficult in this area as the free gas is seismically thin and the available seismic data has a very low fold and frequency, not amenable for AVO analysis. This area needs to be surveyed with 3D seismic data with enough foldage, frequency and quality that could allow the desired analysis.
4. Reprocessing of old data, whether surface seismic or borehole can help interpret the desired detail and so should be resorted to more often.

References

Choo,J., Sudhakar,V.. 2003, LIFT: a new seismic processing technique to LIFT noise and multiples, 2003, CSEG/CSPG Joint National Convention.

Ecker,C.,Dvorkin,J.,Nur,A. 1998, Sediments with gas hydrates: internal structure from seismic AVO, Geophysics, 565-573.

Acknowledgements

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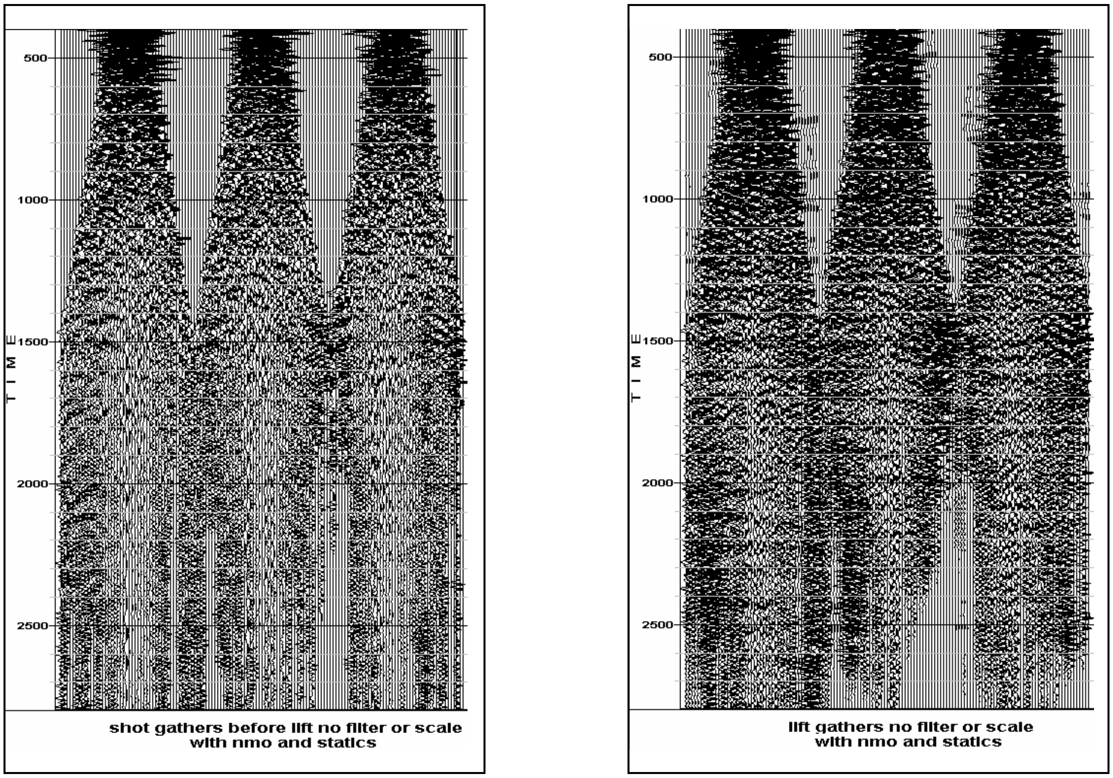

(a) (b)

Figure 1: Shot records (a) before and (b) after application of LIFT

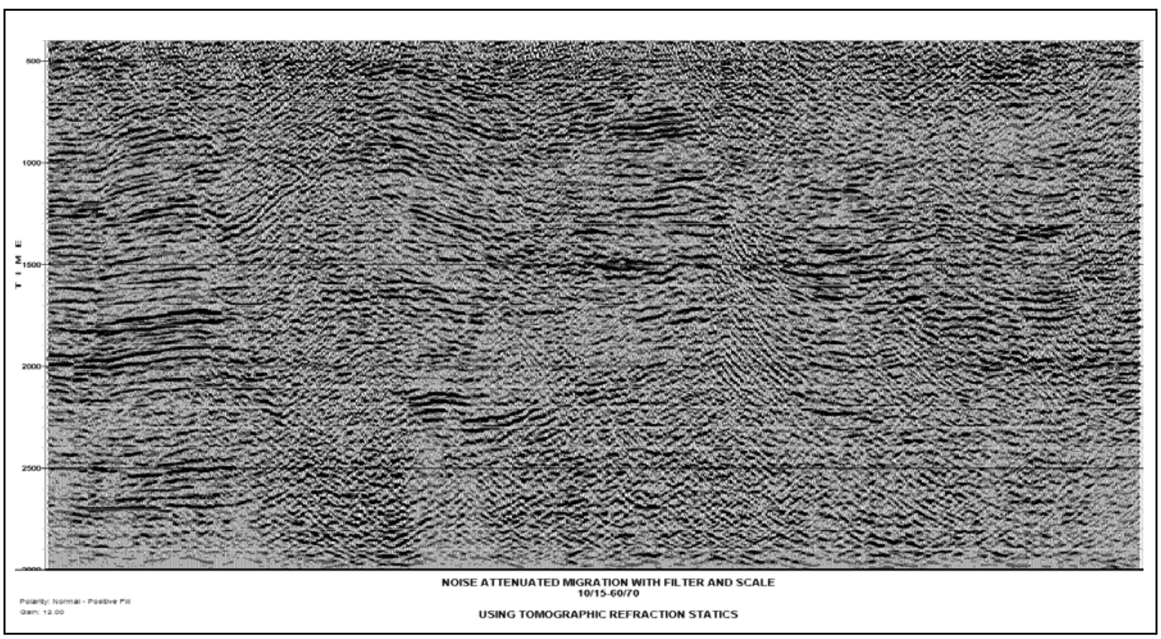

Figure 2: Reprocessed section of 2D profile

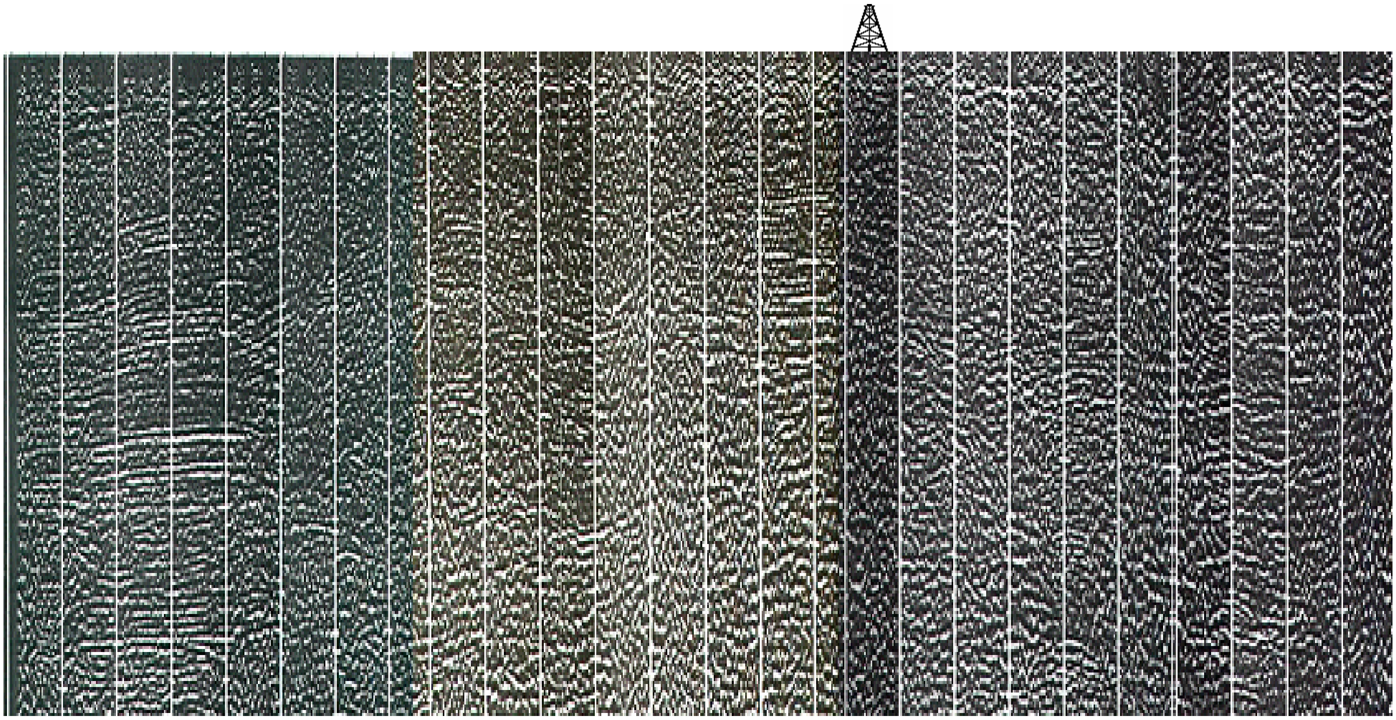

Figure 3: Earlier processed section of the 2D profile shown in Figure 2.

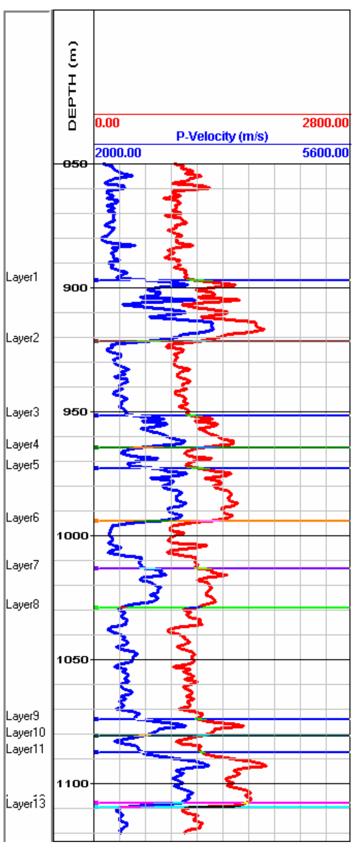

Figure 4: Well log curves with the layer tops indicated. Intervals associated with gas hydrates are indicated with blue formation tops and exhibit high velocities.

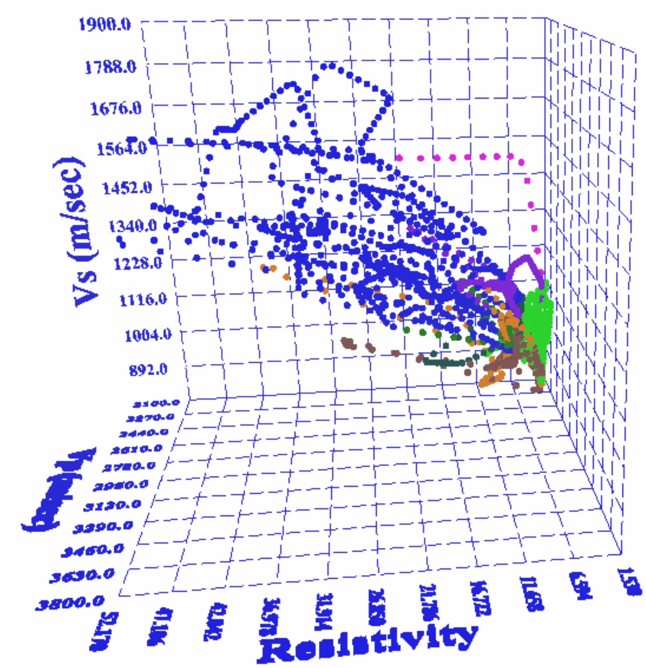

Figure 5: 3D crossplot of Vp, Vs, and resistivity. The hydrate layers indicate large resistivity (depending on saturation).

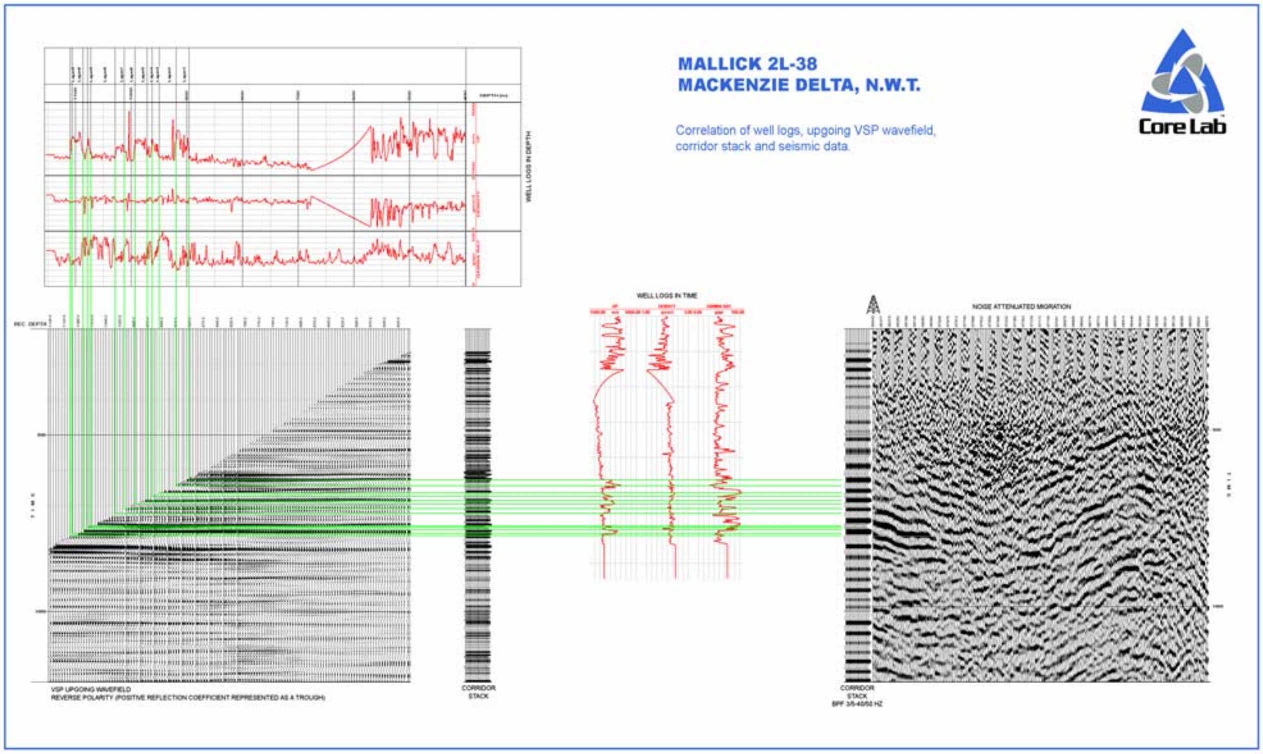

Figure 6: Correlation of well logs, aligned VSP upgoing wavefield VSP corridor stack and surface seismic data. Notice how the reflection levels in the corridor stack line with the reflections on the seismic.

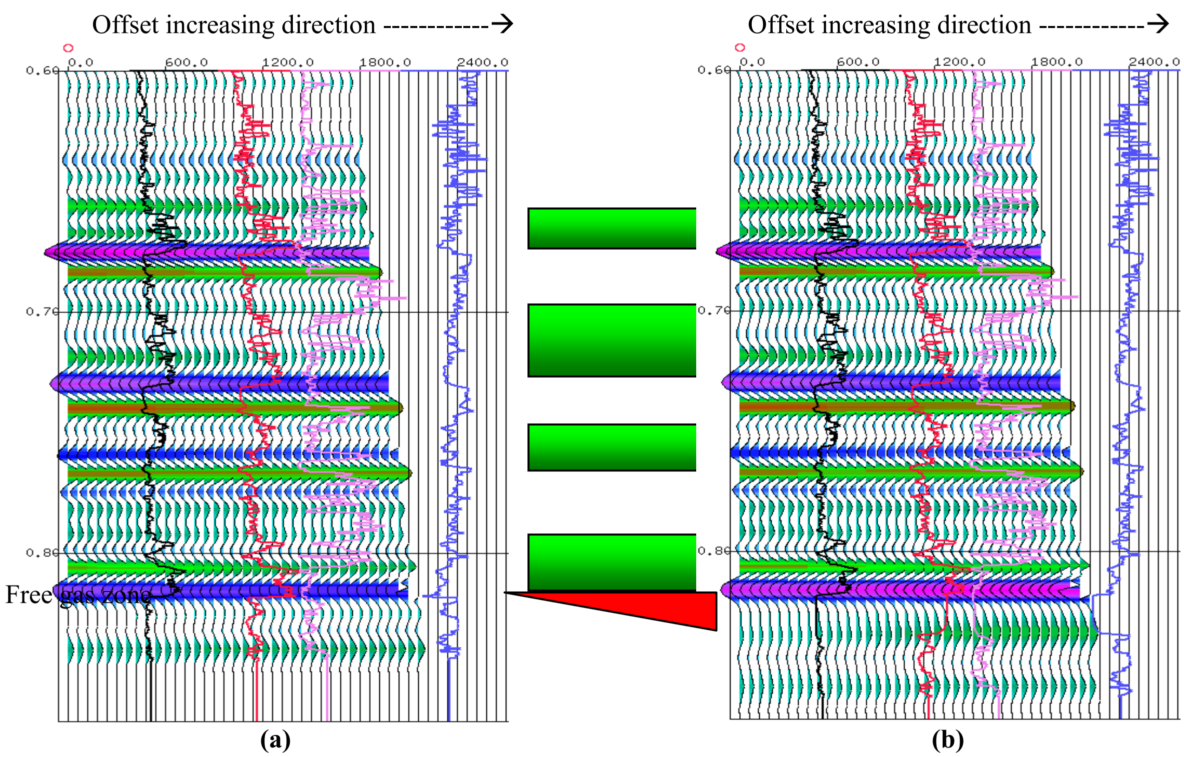

Figure 7:AVO response from original well logs and thickened bottom free gas (a) the original well log with 1.5 m free gas (b) the 20 m free gas. The gas bars indicate high hydrate concentration zones. Black curve is Vp log; the red is Vs, purple is gamma ray, blue is Vp/Vs.