More Confident Interpretation with High Frequency Restoration of Surface Seismic data: a case study

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ABSTRACT

Introduction

A new method for the determination of attenuation, without quantification in terms of Q values has been developed. Referred to as *High Frequency Restoration* (HFR[†]), this method utilizes the frequency decay experienced by direct arrivals at different VSP depth levels in a well, and then compensates the surface seismic data for the frequency losses it has experienced.

A case study is presented for a 3D seismic data volume from southern Alberta. The original seismic data were acquired as three separate surveys and subsequently merged into a single volume. The objective of the interpretation was to develop a detailed description of the Lower Cretaceous Glauconite Sand reservoir for gas storage purposes. A VSP was acquired in the first well drilled in the project and this data was used to apply the HFR algorithm as input to the final interpretation. The improvement in resolution allowed for better imaging of the target reservoir.

Determination of HFR operators

Fig.1 shows the separated downgoing VSP wavefield. A careful glance at the wavelets in the highlighted zone indicates the decrease in the frequencies from the shallow to the deeper levels. The amplitude spectra in *Fig.2* shows the decrease in amplitude of the different frequency components between the shallow depth level (389.6 m) and a deeper depth level (1350 m).

For the VSP downgoing signals (*Fig.1*), the ratio of the change in frequency at successive depths describes the decay of frequency components between those observation points. The change in the trace amplitudes and the length of the wavelet on the first arrivals at successive depth levels is used to estimate the change in the frequency components. An inverse operator (in time domain) is then designed to compensate for that. For successive depth levels, a suite of such operators is generated.

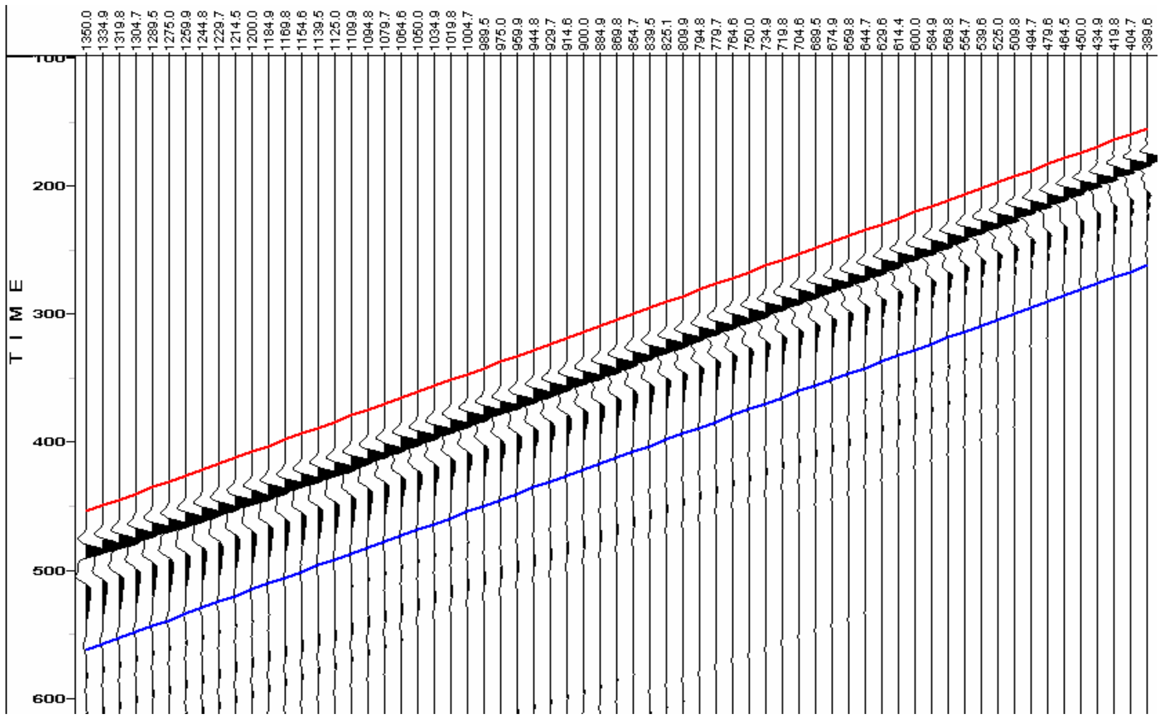

Fig.1: Downgoing wavefield obtained after separation of component wavefields from the VSP total

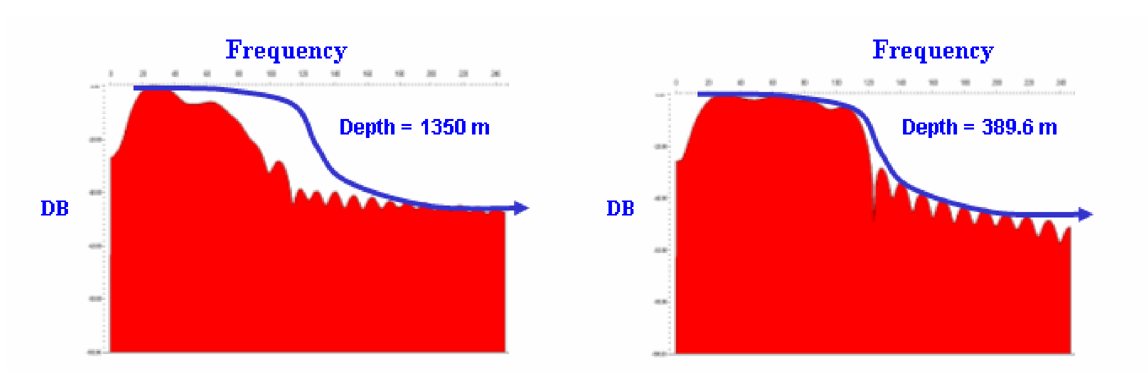

Fig.2: Amplitude spectra of VSP data at a shallow and a deep level

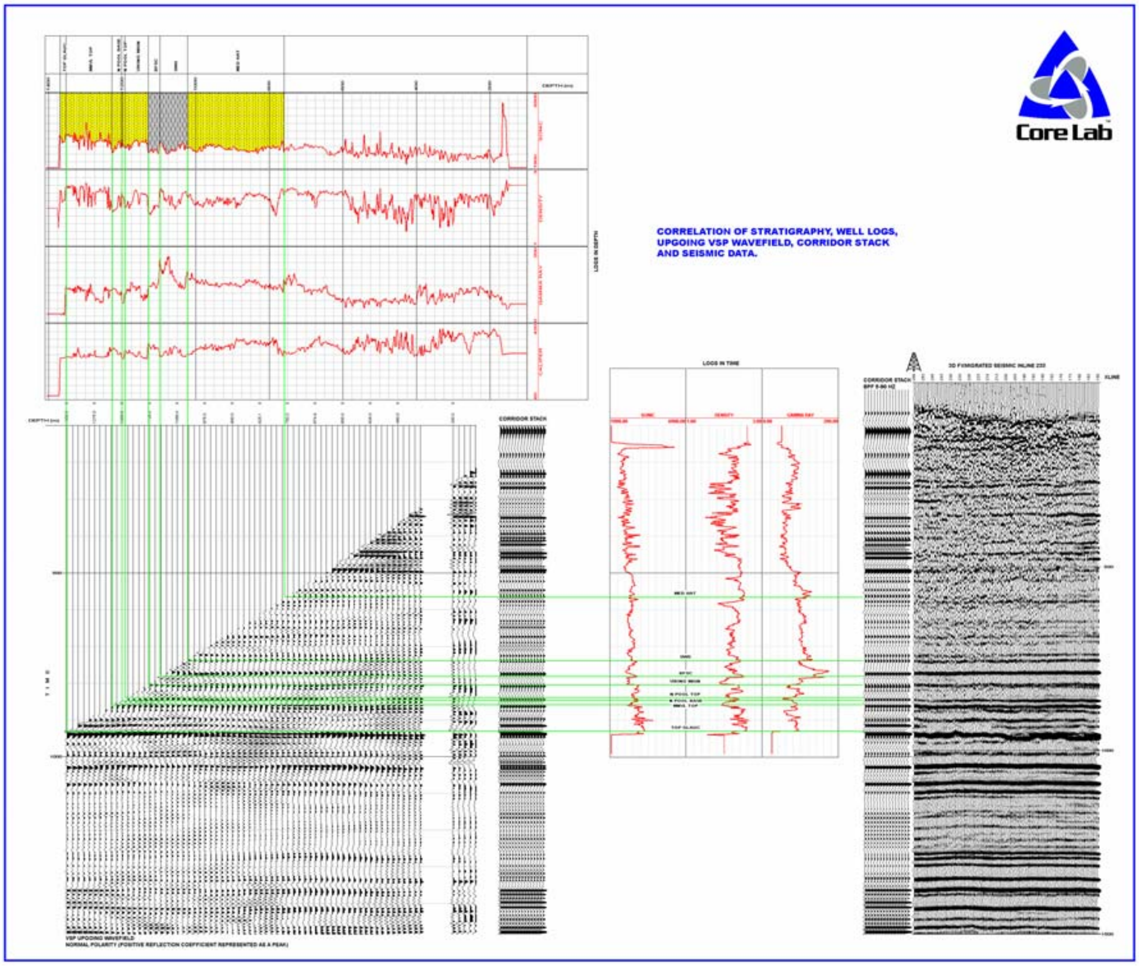

Fig.3: Correlation of well logs (in depth) before application of HFR , VSP up-going wavefield, corridor stack, logs (in time) and surface seismic data

Application of HFR operators to surface seismic data

For application to surface seismic data, first the aligned VSP upgoing wavefield is correlated with the seismic section so that each depth level point is seen in terms of two way time where the predetermined operators need to be applied. Figure3 shows such a correlation. The left hand side of the figure shows the subsurface stratigraphy and the different logs tied (in depth) to the upgoing VSP wavefield. A good correlation here is essential for the accuracy of the correction we are attempting to apply. On the right hand side, we see the VSP corridor stack (in time) shown correlated with logs, a filtered version of the corridor stack and the seismic section. The green lines indicate the depth to time matching of individual formation tops seen on the logs and upgoing wavefield (in depth) with the surface seismic data. This fixes the VSP upgoing wavefield extent, or spread, on the seismic. The first operator corresponding to the first depth level is now assigned a starting time and so this way each determined operator has a corresponding time node point application on the seismic. Thereafter, the filter application is run (as convolution in time domain) on the seismic data. As operators are applied continuously to the stacked data, windowing is avoided. Application of these inverse operators on surface seismic data enhance the frequency bandwidth by restoring the attenuated frequency components.

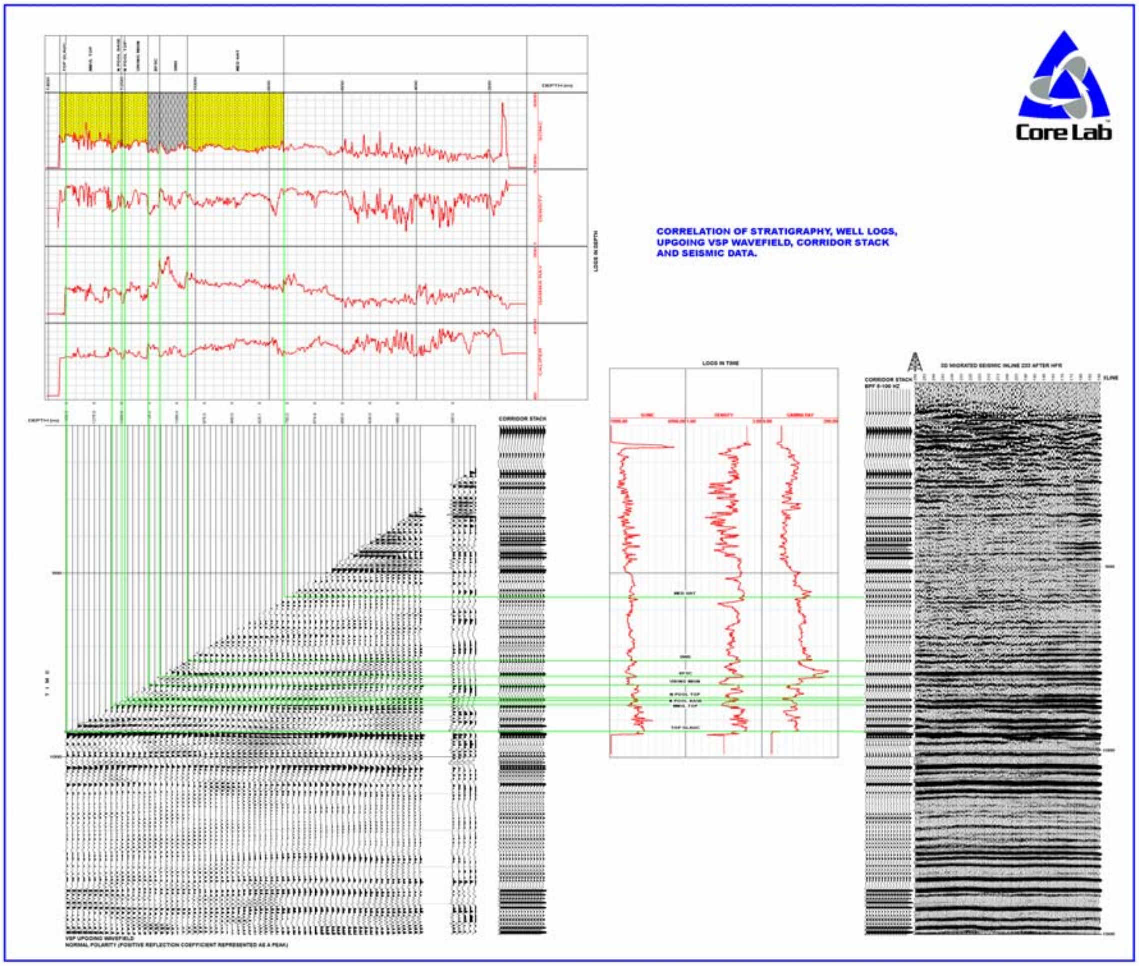

Fig. 4. Correlation of well logs (in depth) after application of HFR , VSP up-going wavefield, corridor stack, logs (in time) and surface seismic data.

Fig. 4 reproduces the display in *Fig. 3*, but with the VSP now being correlated to the HFR compensated seismic data. Note that the bandpass filter required to tie the corridor stack to the seismic has a bandwidth of 5-100 hz as compared to the tie of the original seismic data to the corridor stack which required a bandpass of 5-90 hz.

Results

Fig. 5. shows a more detailed comparison of the effects of HFR processing on the seismic data. On the left is a tie of the corridor stack to the original seismic data at the Cretaceous Glauconite sand level. On the right is the same corridor stack tied to the HFR processed seismic. The bandpass filter applied to the

corridor stack is 5-100 hz. Note the improved waveform tie and improved temporal resolution in the HFR filtered seismic.data.

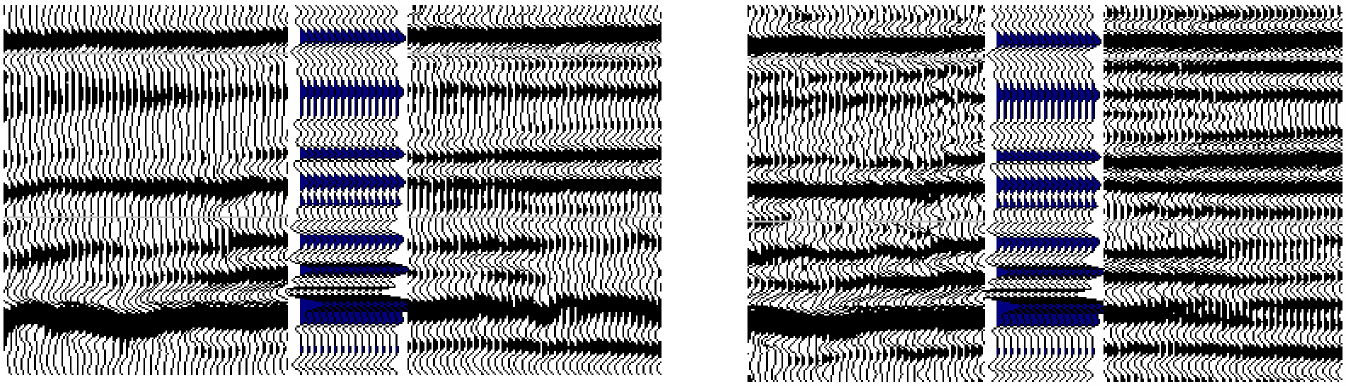

Fig. 5. On the left is the seismic tied to the HFR corridor stack prior to match filter application. Note the poor tie to the bandpass matched corridor stack. On the right is the HFR match filtered data tied to the appropriate bandpass matched corridor stack, showing notable improvement in resolution.

With improved resolution of the target Glauconite sand a more precise estimation of reservoir unit thickness could be made from the seismic data. In addition, improved resolution of the 3D seismic data allowed for the interpretation of small scale faults throughout the data that were not previously evident on the originally processed 3D data. This fault information provided useful input to the design of horizontal drilling trajectories in the project development.

Fig. 6 is a comparison of coherence slices taken from the original seismic volume on the left and the volume with HFR filtering applied on the right..

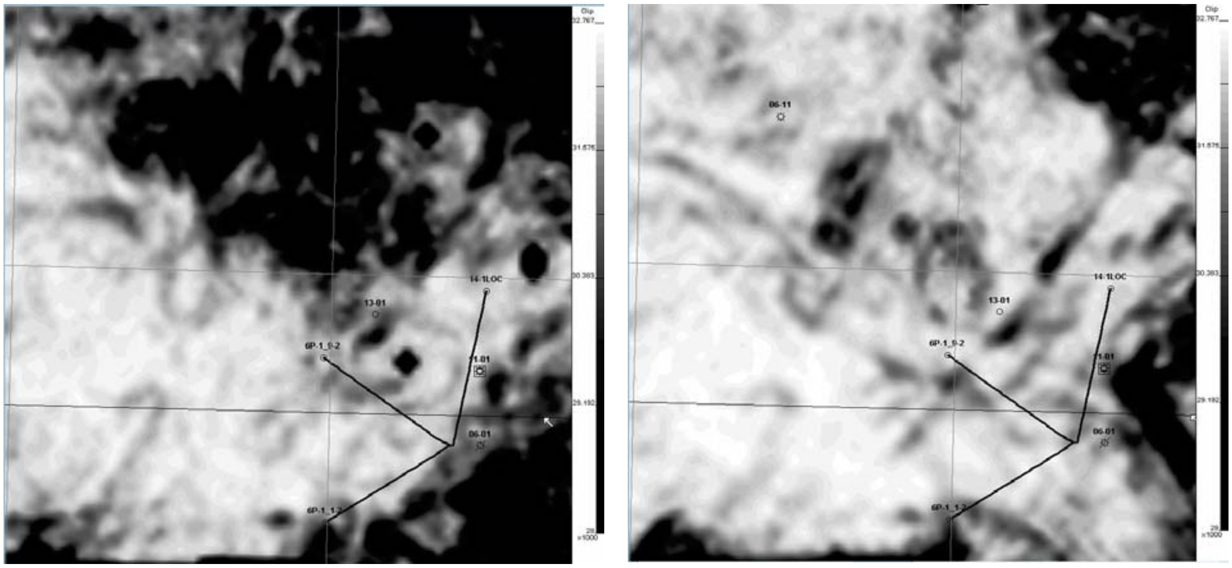

Fig. 6. Comparison of coherence slices of the original seismic on the left with the HFR filtered data on the right. Note the more clearly defined fault character in the HFR filtered seismic.

The HFR filtered seismic more clearly reveals the linear fault traces that strike NW-SE and NE-SW. The horizontal well that tracks from SE to NW in the timeslices encountered faults at the same locations shown by the HFR data. It is clear that the improved resolution of the HFR process provides benefits in the mapping of subtle fault features.

Conclusions

High frequency restoration applied to seismic data provides the opportunity to generate superior seismic interpretations by virtue of improved bandwidth. This easily applied process provides yet another valuable benefit to the acquisition of VSP data in both exploration and development environments. The compensation for frequency decay due to Q allows for the investigation of more subtle targets at depth and is a valuable tool in the interpreter's hands.