High Frequency Restoration of Surface Seismic data

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Often we come across examples where the first-time processed 3D seismic volume leads to interpretations that sometimes are geologically suspect, e.g. cases involving complex faulted patterns or tricky stratigraphic plays. Similarly, dry well analysis may cite fault displacements being small or seismic data being obscure as reasons for the dry holes. In such cases, the usual practice is to add a new version of the 3D volume, which has had some target oriented processing carried out. This is done to obtain some improvement in the zone of interest, which hopefully would lead to a more accurate interpretation. In some cases this helps, but in others still some questions remain unresolved.

More often than not, in such cases a more accurate stratigraphic interpretation is warranted, but the available bandwidth of the data is inadequate to image or resolve the thicknesses of many of the lithounits seen in the wells.

This problem can be addressed by having data of reasonable quality and augmenting it by some frequency restoration procedure that would improve the vertical resolution. This enables confident mapping of subsurface horizons of interest, clarifies detailed geological settings and eventually leads to more profitable seismic exploration programs.

We are aware that seismic waves propagating in the subsurface get attenuated. This loss is frequency dependent -higher frequencies are absorbed more rapidly than lower frequencies, such that the highest frequency recovered on most seismic data is usually about 80Hz. Attempts are usually made to determine the subsurface attenuation in terms of the attenuation constant (α) or the quality factor (Q). The conventional methods used for their determination from surface seismic data, not only have their limitations but also have a certain level of uncertainty.

A new method (patent pending) for restoring high frequencies within the seismic bandwidth has been developed. This is different from any of the conventional methods practised in the industry and utilizes the amplitude/frequency decay experienced at different VSP depth levels in a well. For VSP downgoing signals recorded at different depth levels, the ratio of change in trace amplitudes at successive depth would describe the decay of frequency components between those observation points. This fact is utilized to first determine the amplitude decay resulting from frequency attenuation from downgoing VSP traces and then used to restore those frequency components that have been attenuated in the surface seismic data.

The above frequency restoration procedure has been run on seismic data from several different areas, both land and marine, and convincing results have been obtained. Fig.1 shows the correlation between stratigraphy, VSP upgoing wavefield (zero offset), VSP corridor stack and a segment of the seismic profile drawn from a 3D seismic volume, with and without frequency restoration. Notice the improvement in resolution and continuity. The reflections at the indicated levels (curly bracket on the right) exhibit greater continuity and also there is a very good correlation between the two after frequency restoration.

The high frequency restoration of the seismic data has also been evaluated by running Coherence Cube™ analyses on the seismic volumes before and after frequency restoration. Fig.2 shows the seismic expression of a reef before and after frequency enhancement. The boundary of the reef is not seen clearly on the horizon slice from the Coherence Cube before, but seen quite crisp-and-clear on the Coherence Cube run on the seismic after frequency restoration.

The procedure enunciated here is robust and helps to define trends better leading to more confident interpretations. Such applications could redefine prospects, which in some cases may have been declared unsuccessful based on interpretation of seismic data with poor bandwidth.

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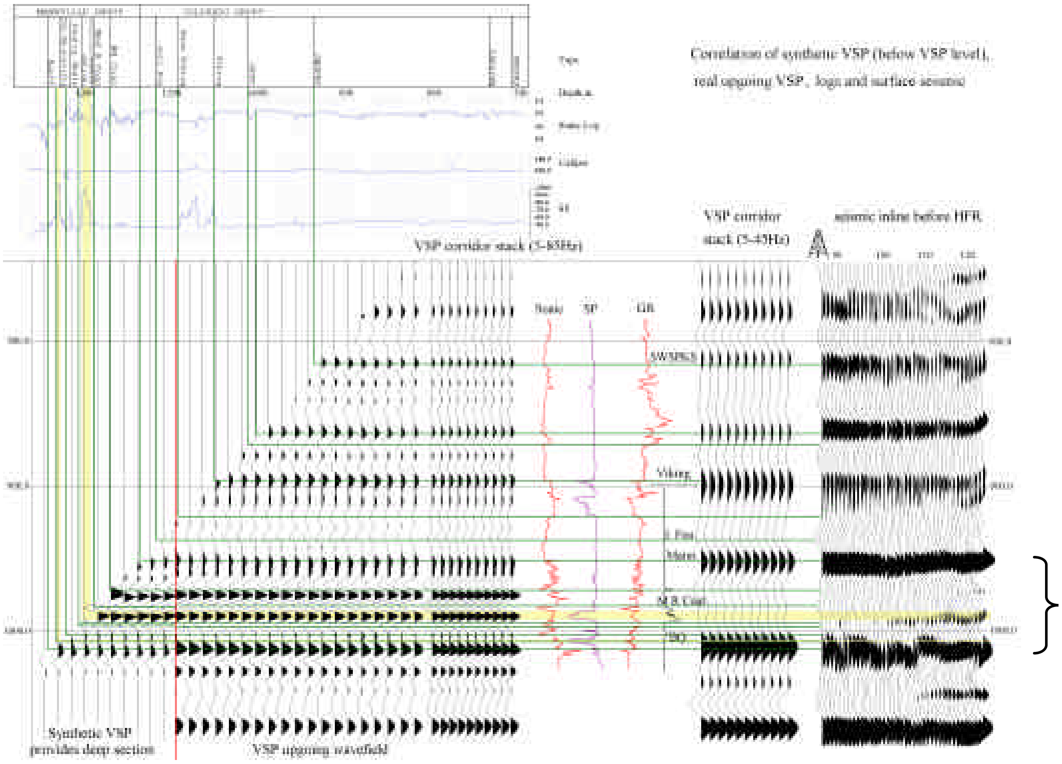
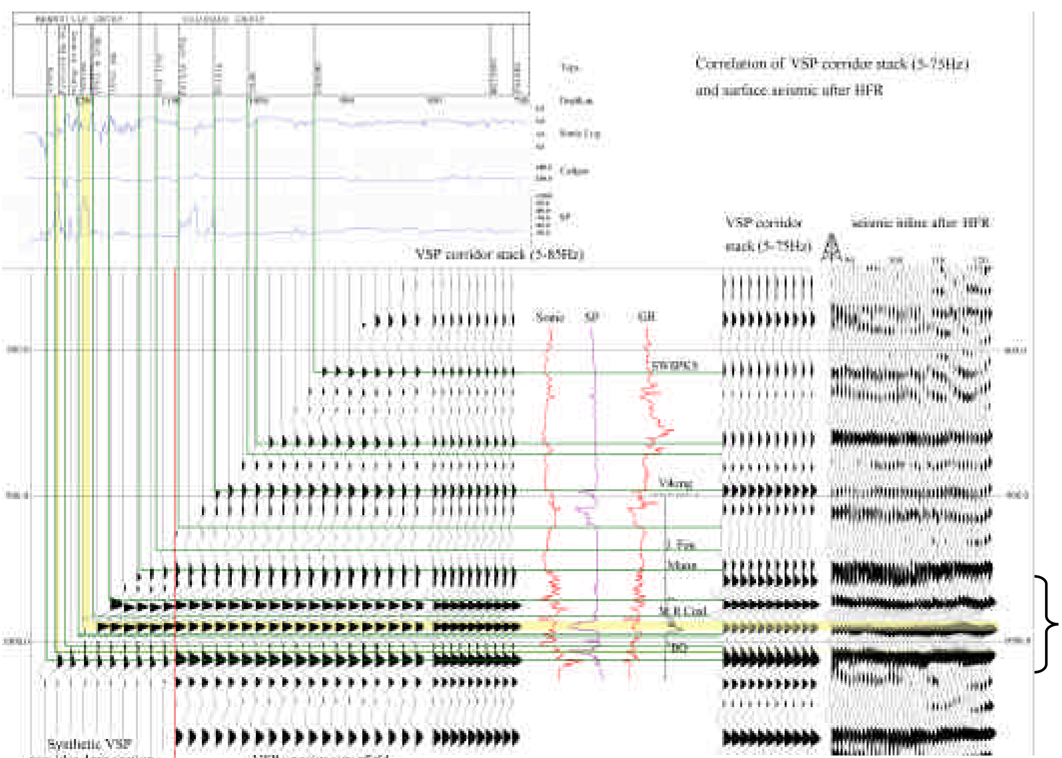


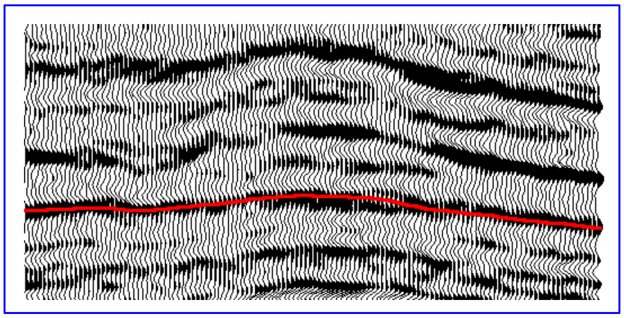
(Data courtesy: Conoco Canada Resources Ltd.)

Fig.1(a) : Correlation of stratigraphy, VSP upgoing wavefield, well logs, VSP corridor stacks and seismic before high frequency restoration

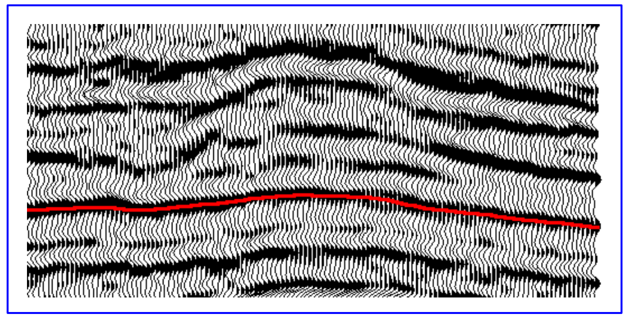


(Data courtesy: Conoco Canada Resources Ltd.)

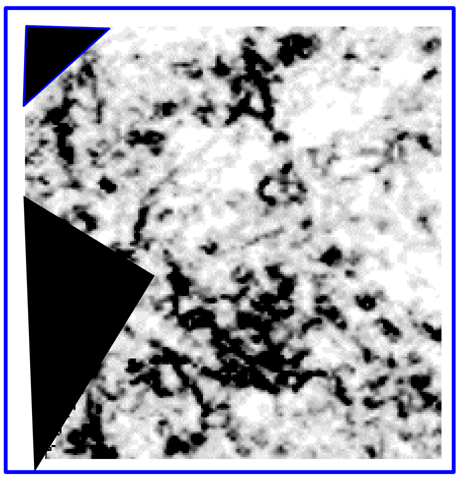
Fig.1(b) : Correlation of stratigraphy, VSP upgoing wavefield, well logs, VSP corridor stacks and seismic after high frequency restoration



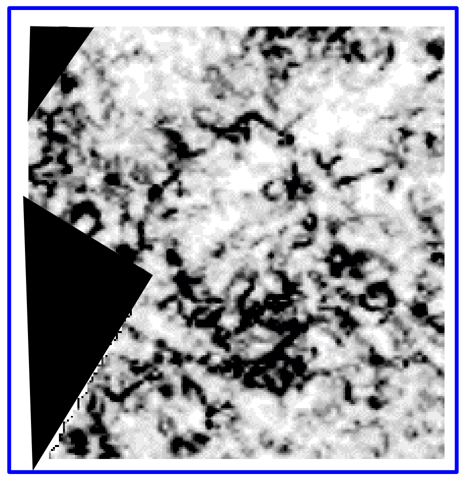
Segment of seismic line showing the reef



Segment of seismic line after high frequency restoration showing the reef



Reef not seen clearly on coherence horizon slice



Reef seen clearly on coherence horizon slice after high frequency restoration

(Data courtesy: WesternGeco)

Fig.2