Walkaway VSP Processing and Q estimation: Pikes Peak, Sask.

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Abstract

A 3-component walkway VSP survey was conducted at Husky Energy Inc.'s Pikes Peak heavy oilfield in September, 2000. The zero-offset (23 m) data are processed using the ProMaxVSP system. The resultant VSP corridor stack ties the synthetic seismogram and surface 2D seismic very well. In addition, data from the 90m-offset and 450m-offset data are analysed here. A P- and S-wave velocity model is created for parametric wavefield separation. Finally, using the spectral ratio method, a Q factor is estimated from zero-offset. The Q value around the target sands is about 74.

Introduction

The Pikes Peak heavy oilfield, 40 km east of Lloydminster, Sask., is stratigraphically located in a major channel within the Waseca formation of the Mannville group, Lower Cretaceous. The permeability of the reservoir is extremely high at 5-10 Darcy's. The high viscosity of the oil may be result of the low sediment compaction. CREWES and the Alberta government (AOSTRA) in collaboration with Husky Energy Inc. are conducting a detailed study of Husky's Pikes Peak reservoir. As part of this study, a 3-component walkaway Vertical Seismic Profile (VSP) survey was acquired in September 2000. The multi-offset VSP was conducted in well 141/15-06-50-23W3 by Schlumberger Canada, using their 3-component, 5-level ASI tool. A MERTZ HD18 Buggy vertical vibrator, using a linear sweep from 8 Hz to 200 Hz, served as the source at zero-offset (23 m) as well as at five other offset locations from 90 m to 450 m with 90 m increment. The downhole geophone was clamped from 514.5 m to 27 m measured from the KB with 7.5 m spacing.

Processing

Zero-offset data

The zero-offset (23 m) data are processed using ProMaxVSP software, including processes as: geophone level (vertical) stack, spectral analysis, band-pass filter (8-12-190-200 Hz), first-break time pick, amplitude recovery and trace balance, median filter to separate down-going and up-going wavefields, deconvolve upgoing waves using enhanced downgoing waves, align deconvolved up-going wave in two-way time, 2nd median filter to enhance upgoing events, and corridor stack (Figure 1).

The compressional-wave sonic log (DT-P) and density log (DEN) of the well 15-06 are input into ProMaxVSP to create a synthetic seismogram. A 8-12-190-210 Hz zero-phase ORMSBY wavelet is used here. The corridor stack and synthetic match very well around the target zones. The VSP corridor stack is also compared with the 2D surface seismic line which cross well 15-06 at north end (left side) in Figure 2.

Offset data

The 90m and 450m offset data were processed using Seislink software (Western Geophysical). The vertical component shows that there are strong source-generated waves propagating downward. After horizontal-component rotation using hodograms, we again see these events which we interpret to be S-waves. Models of P-wave velocity, S-wave velocity and density are created from the logs of well 15-06 and used for parametric wavefield separation. Using vertical and radial component data plus the model, four wavefields, down-going P, down-going S, up-going P and up-going S, are obtained. The results indicate that we have fairly clean downgoing P-waves, the upgoing P data also look good except some white stripes. Both down and up shear wave are not very well resolved.

For 450m-offset data, it is observed that the first arrivals of vertical component have reversed polarity at about depth of 160 m. The recorded first arrived energy above 160 m may be refraction. Using same model, the parametric wavefield separation is applied to the 450m offset data. To avoid the effect of refraction, the start station is chosen from #25 (207 m). The results (Figure 14) looks reasonable, and with the same problems of 90m-offset.

Q-factor Estimation

The attenuation of seismic waves is of interest in the analysis of vertical seismic profile (VSP) data for two reasons. First, anelastic attenuation degrades the frequency content of seismic waves - which should be remediated. Second, attenuation has been recognized as a potentially useful petrophysical value. Here, we use the standard spectral ratio method to investigate the Q values of Pikes Peak, based on the assumption of frequency-independent Q (the logarithmic ratio is shown in Figure 3). The input data for estimating Q factor is the down-going wave from zero-offset VSP.

This VSP survey was conducted in a fairly shallow well from 27 m to 514.5 m. The distance between two stations for spectral ratio calculation should be at least several wavelengths. In this case, we use 15x7.5=112.5 m interval. In order to make the result more stable, we use adjacent stations to get the average amplitude spectrum. The Q factor calculated from single station ratio between #49 and #64 is 44.0, and 48.0 from three-station average, and 46.6 from a five-station average. There are no significant differences between the results, which indicated that the signals around these two stations (#49 and #64) are stable and reliable.

Above station #35 (280m), the estimated Q values are negative, which has no physical meaning. Below that depth, Q values are reasonable. From 280 m to 430 m, the shale dominated formation has lower Q factor about 46 (Table 1). The target sandstone shows a bit higher Q value of 74.

Station #	Depth Range (from KB)	V-int (m/s)	Q
35 ~ 45	282 m ~ 357 m	2300	45.2
45 ~ 55	357 m ~ 432 m	2350	48.2
55 ~ 65	432 m ~ 507 m	2500	74.0

Table 1. Q factors for well 15-06.

Conclusion

Zero-offset data have higher signal-to-noise ratio. The corridor stack of zero-offset VSP data ties well with the synthetic seismogram of well 15-06. 90m-offset data can get good P wave component. The 450m-offset data demonstrates very strong refraction energy above 160 m depth. This refraction affects the necessary wavefield separation. To avoid this, shallow stations above 200 m are not used. Using the spectral ratio method, a Q factor can be estimated from zero-offset down-going wavefield. The Q factor around the reservoir sand is about 74. The upper shale shows lower Q value about 46. Above 280 m, the estimated Q is not meaningful possible due to changes of source signature, geophone coupling condition, cement condition and casing program.

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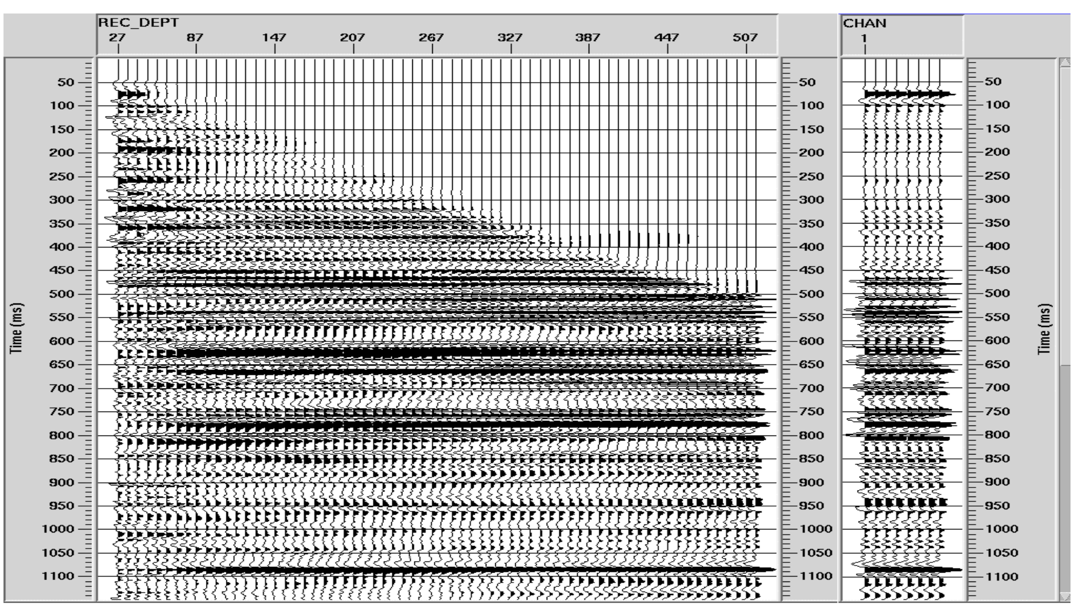

Fig. 1. Enhanced deconvolved up-going events and final corridor stack.

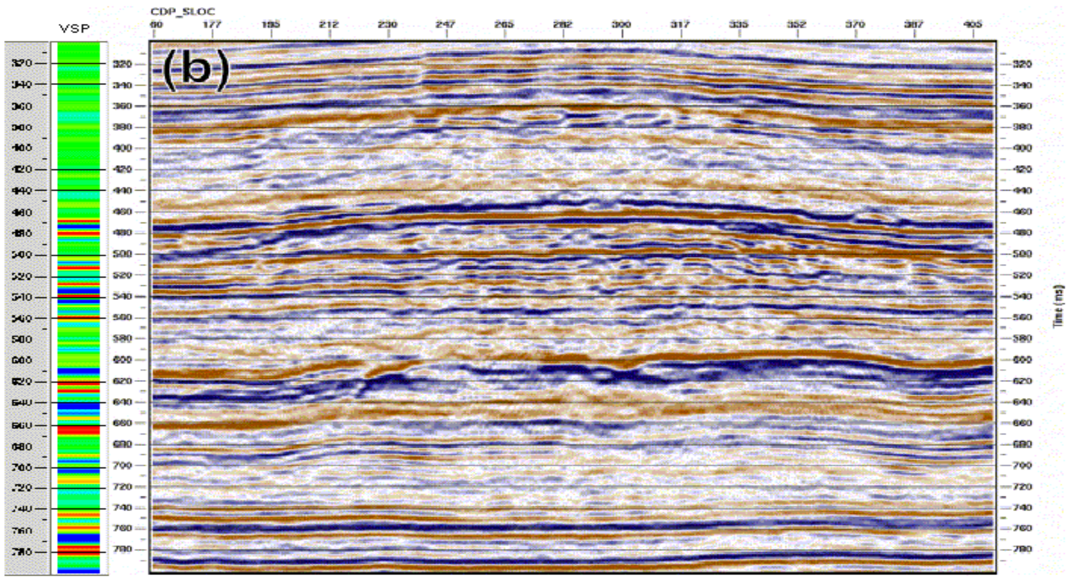

Fig. 2. Comparison of VSP corridor stack (left) and 2D surface seismic line (right).

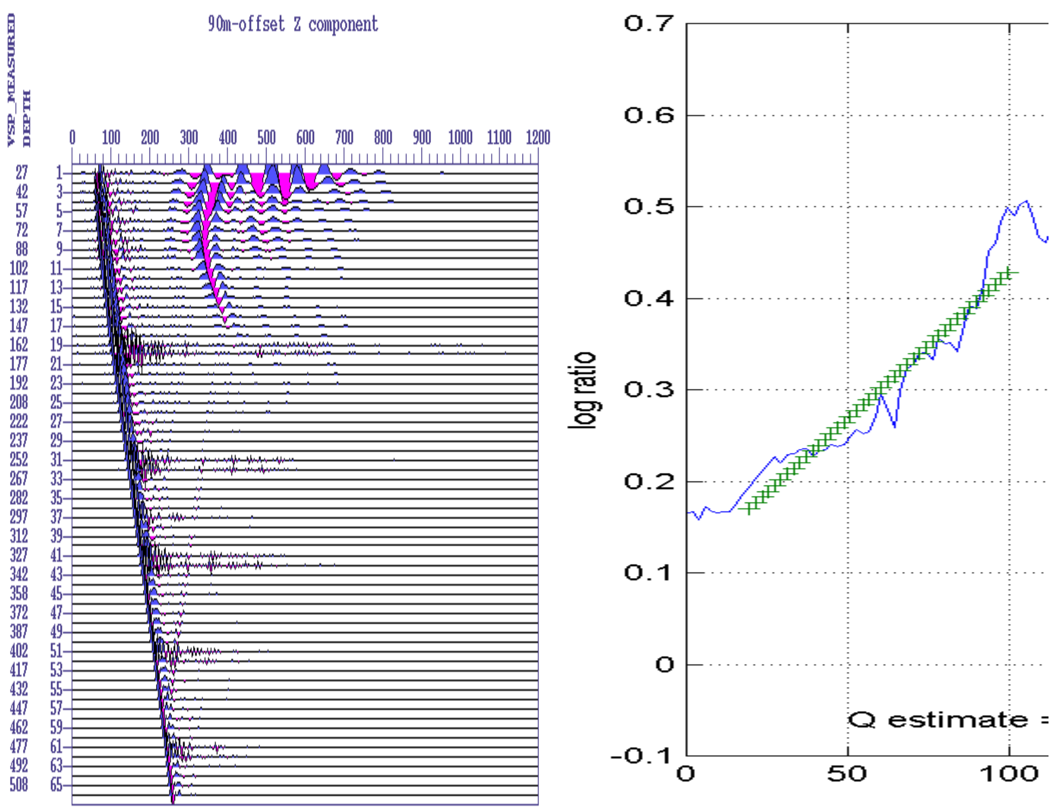

Fig. 3. Raw vertical channel VSP data and the logartithmic spectral ratio plot to determine a Q value.