FIBRE-OPTIC VSPS: BOREHOLE SEISMIC REVOLUTION IN AUSTRALIA

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SUMMARY

The borehole seismic industry is undergoing a quantum leap in the acquisition technology. The standard borehole seismic imaging tools such as accelerometers and geophones are now being replaced by the fibre-optic (FO) acquisition for basic surveys such as zero-offset vertical seismic profiles (ZVSPs) and checkshots. This saves significant time, and associated rig cost, whilst providing sufficient data quality for basic interpretation. Schlumberger's heterodyne distributed vibration sensing (hDVS) technology, deployed within a wireline heptacable, was recently used in Australia to acquire a zero-offset VSP dataset, whilst simultaneously taking downhole core measurements. The hDVS technology is based on the distributed acoustic sensing (DAS). This presentation shows the acquired dataset and the basic processing results. A comparison between the FO and conventional dataset, in the nearby wellbore, as well as surface seismic and synthetics is made showing remarkable similarity between all datasets, validating the FO data.

Key words: Fibre-optic, borehole seismic, heterodyne distributed vibration sensing, zero-offset VSP, DAS

INTRODUCTION

Borehole seismic (BHS) measurements such as checkshots and zero offset vertical seismic profiles (ZVSP) provide the only measurement of vertical velocity in a borehole, which is a crucial input into prestack depth migration (PSDM) processing of surface seismic data. Emergence of fibre-optic (FO) technology in the oil and gas industry is revolutionising the way these data are recorded. In broad terms, the BHS data are recorded using surface sources, vibroseis or impulsive, and downhole tools. Over time, downhole tools have progressed from single-component, single-sensor packages to multilevel three- or even four-component shuttles and now to FO conveyance (Figure 1).

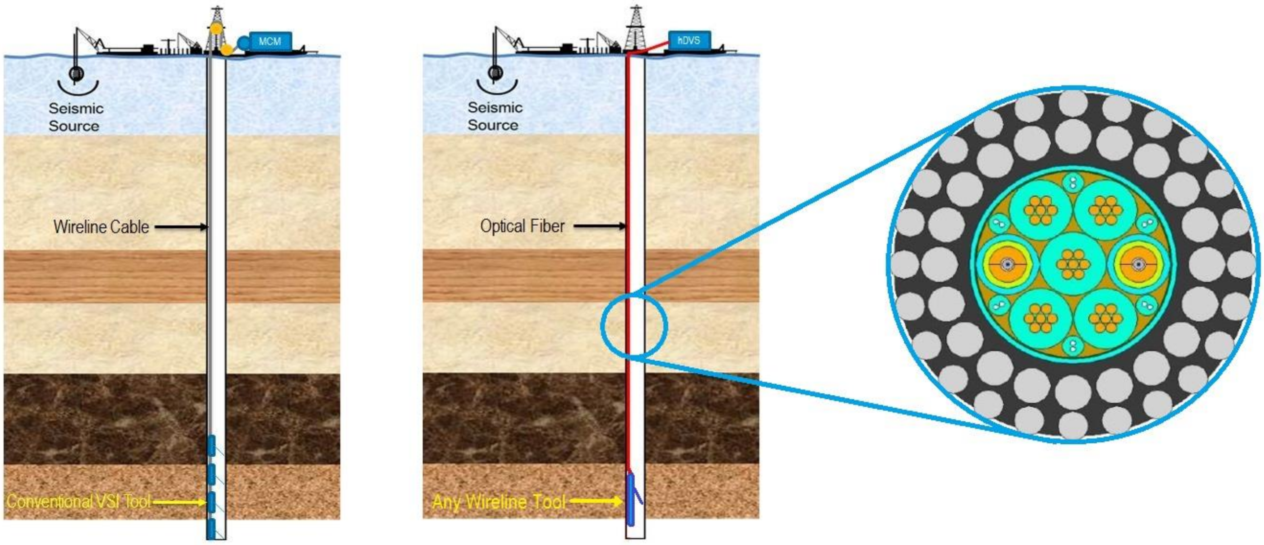

Figure 1: Conventional and fibre-optic acquisition scenarios and hybrid wireline cable (modified after Kimura and Galybin, 2017).

The FO conveyance is based on the distributed acoustic sensing technique (DAS) and has the potential to significantly reduce the time taken to acquire BHS data (Hartog *et al.*, 2013, Kimura *et al.*, 2016). Conventional tools, which range from four to over a hundred shuttles, require significant time to rig up. The larger the number of shuttles in the toolstring, the longer rig-up time and shorter the acquisition time. Longer toolstrings allow fewer surface shots and hence result in faster acquisition along the wellbore and vice versa. It is common to pick the number of shuttles within the conventional BHS toolstring based on the comparison of depth (and hence acquisition time) of the well and how long it takes to make up the toolstring. For the same reasons, the BHS measurements are often omitted from any investigations of the overburden, leaving a sizable gap in the shallow velocity knowledge, which is so crucial to PSDM processing of surface seismic data. These considerations are not applicable to the FO technology.

FO acquisition is based on the distributed vibration sensing (DVS) system and can be incorporated within a standard wireline hepta-cable (Varkey *et al*., 2008). Such configuration allows acquisition of BHS measurement simultaneously with other logging runs, such as pressure measurement on the MDT* modular formation dynamics tester toolstring or downhole coring with the XL-Rock* large-volume rotary sidewall coring service (or similar tool). Both of these scenarios were trialled for the first time worldwide in Australia. The second one is the focus of this paper.

METHOD AND RESULTS

In a recently drilled well, the desire to acquire knowledge of the overburden became the main driver for acquisition of a world-first FO VSP whilst simultaneously coring with the XL-Rock downhole wireline coring tool. Such simultaneous acquisition was enabled by utilising the hybrid (i.e., FO and conventional) wireline heptacable. In such a cable, two of the seven electrical cables contain single-mode optical fibres. The cable's 10,000 lbf safe working load is sufficient for logging, down to 5 km, by the majority of downhole tools, including the XL-Rock coring service (970 lbm).

The acquisition was performed whilst coring using the heterodyne DVS (hDVS) technique (Frignet and Hartog, 2014). The hDVS acquisition time was 40 minutes. The XL-Rock tool was anchored in preparation for coring operations to maintain quiet downhole setting. The acquisition time for a conventional four-level tool such as the VSI* versatile seismic imager tool would have been 6 hours, based on the logging interval of 2 km, 5 minutes per four-level tool, and 3,600 ft/hr logging speed between tool settings. The acquired hDVS data are shown in Figure 2 (top left).

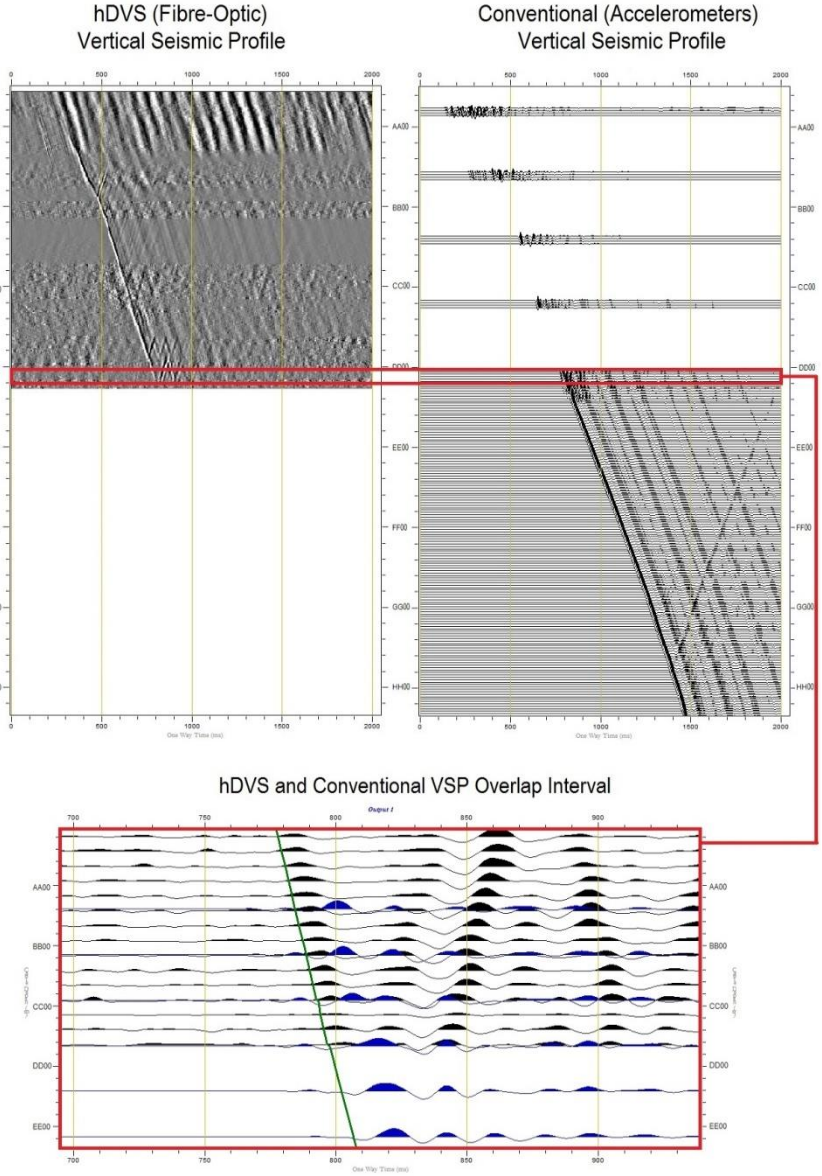

Figure 2: ZVSP acquired using FO (top left) and conventional (top right) acquisition methods and a zoomed-in view of the overlapped traces (below): hDVS VSP data (black) and overlapping conventional VSP traces (blue).

In this well, as planned, the conventional VSP was acquired with a four-level VSI tool with several levels that overlapped with the hDVS BHS survey (Figure 2, top right). The transit time of the conventional ZVSP data, shown in blue in Figure 2, correspond to the hDVS transit time to within 0.5 ms. The conventional ZVSP exhibits some effects of casing, and the time picks were made using hodogram analysis of the three-component conventional data.

The advantage of the hDVS acquisition over the conventional approach is that velocity data were acquired in an interval where it was not favourable to do so before. This exhibits the first real measurement of velocity in the shallow section in this area. The waveform data were also processed to generate, along with the conventional VSP, a corridor stack along the well and a set of calibrated synthetics. The processing parameters were chosen to be spatially the same: velocity filters (Hardage, 1991) of 105 m in length and deconvolution in the 10- to 80-Hz range to be able to compare the processed results directly with each other (conventional VSP has frequency range of 3 to 100 Hz). Figure 3 shows the processing results. The correlation between the hDVS and the conventional VSP is excellent, even for targets that are significantly deeper than the deepest hDVS measurement.

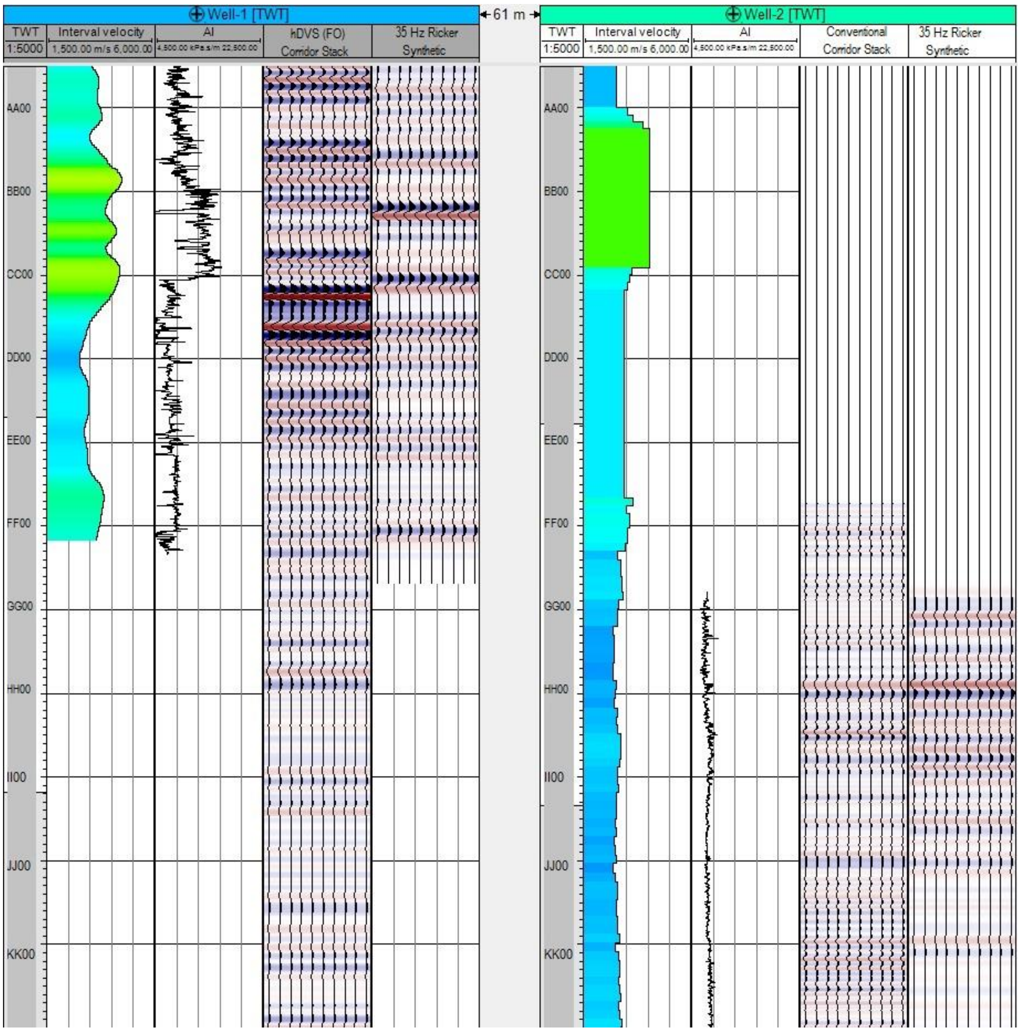

Figure 3: hDVS VSP processing result (left panel) and conventional VSP processing result (right panel).

The processing results of the hDVS and conventional ZVSP are consistent with each other in the overlap interval as well as the 1D synthetics generated within each interval. The presence of a minor dip below the hDVS acquisition interval results in a minor mis-tie between two VSP datasets below the FF00 depth. However, they tie at and above that depth. Hence, due to the lack of dip in the overburden, a single corridor stack can be generated by merging the hDVS and the conventional ZVSP data. This exhibits a unique opportunity that can be used for qualitative and quantitative analysis of surface seismic data along the entire length of the wellbore, which was not available before.

CONCLUSIONS

The world's first FO VSP measurement while coring on a wireline toolstring has been presented in this paper. The acquisition time for such a survey was reduced from 6 hours to 40 minutes and allowed acquisition of overburden velocities in the study area. Moreover, the acquired hDVS data exhibited reflectivity that is consistent with the conventional VSP and synthetic seismograms. This presents a unique opportunity to utilise this groundbreaking technology to acquire VSP data in logging intervals where such measurement would not be commonly acquired.

ACKNOWLEDGMENTS

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