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DOI:10.1190/1.1885849

Single well Seismic imaging and Reverse VSP applications for the downhole seismic vibrator

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SUMMARY

Single well seismic imaging and reverse Vertical Seismic Profiling have long been regarded as important new technologies, but their implementation has not yet been realized. One reason has been the lack of a borehole seismic source that is powerful enough to transmit seismic energy over long distances but would not swamp receivers in the same borehole with tube wave noise. The borehole-clamping, hydraulic vibrator, recently developed under a Cooperative Research and Development Agreement (CRADA) between government, GRI, and industry, is a candidate for these applications inasmuch as it can transmit a considerable amount of seismic energy into the formation with little or no accompanying tube wave noise. Several surveys have been conducted to test the vibrator's potential for these applications, and plans are underway to build a second vibrator in which a clamped receiver array can be attached below it.

INTRODUCTION

Borehole seismology has generally meant either VSP or crosswell tomography and reflection imaging. Although both can provide important reservoir information, they are generally limited to two dimensions, and in the case of crosswell the limitation extends to the requirement of two (or more) suitable wells. The cost of data acquisition is also quite high and can often exceed the value of the information obtained Erom the survey. This is especially true for short well spacings. Nevertheless, industry has long recognized that borehole seismology has the potential to significantly improve reservoir imaging given the higher frequency bandwidth and presence of both P and Shear waves in the recorded data.

To realize this potential, industry and government joined together to form a CRADA in order to design and build a powerful, borehole seismic source, which has generally been regarded as the most important new component for the technology. The CRADA members comprise Sandia National Laboratories, representing the U.S. Department of Energy, Raytheon Aircraft, the Gas Research Institute, Pelton, Chevron, Exxon, Amoco, and Conoco. A borehole-clamped, hydraulically driven, axial vibrator was completed early this year and has already been used in a number of surveys. These surveys were planned to test the vibrator's capability in reverse VSP's, and single-well imaging, two new applications in borehole seismology that been at the heart of the perceived high potential for this technology.

REVERSE VSP AND SINGLE WELL IMAGING

A conventional VSP survey, with the source at the surface and a small array of receivers in the borehole, cannot reasonably record the data volume required for 3-D coverage. A reverse VSP, on the other hand, with the source in the borehole and receivers on the surface, can sample a large 3-D volume around the borehole with not much more field effort than recording a single-offset, conventional VSP. The requirement for reverse VSP's is of course the seismic source, which must be powerful enough to transmit energy to the surface without damaging the borehole casing or cement bond.

There have been several attempts at single-well, long-distance, seismic imaging with the objective of mapping salt flanks or other near-vertical structures. However the high engineering costs of attaching a seismic source to a receiver array, the difficulty in deploying them together, and the dangers in deploying them separately have limited the scope of these attempts to unclamped seismic sources and receivers, resulting in tube wave noise many thousands of times stronger than any potential reflection or backscattered signal. As with reverse VSP's, however, there is significant value in the technology, and an industry consortium has made a considerable effort at Bayou Choctaw, Louisiana to help in its successful development. The Bayou Choctaw program has comprised the testing of a number of candidate seismic sources included the hydraulic vibrator. In most cases the receivers were placed in a nearby well, bypassing the deployment difficulties, but allowing for salt flank reflections to be recorded. The data quality recorded by the vibrator was very good, and a number of salt reflections have been identified.

The most serious noise sources are the direct arrivals from the source well something which will be avoided in a future single well system.