Tube-Wave Effects in Crosswell Seismic Data

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RESEARCH OBJECTIVES

The main goal of this project is to develop a new technology that will improve the quality and resolution of seismic monitoring in natural underground reservoirs. The main innovative part of this technology is the use of tube waves as primary signal-carriers, which will provide a relatively inexpensive seismic monitoring method for use during management of real-time fluid production.

APPROACH

A tube wave is an interface wave for a cylindrical boundary between two media, typically borehole fluid and surrounding elastic rock. These waves have large amplitudes and can propagate long distances without substantial decay. They are traditionally regarded as a source of high-amplitude noise in borehole seismic data, and consequently much effort goes into their suppression and elimination from seismic recordings.

Recently, analysis of crosswell seismic data from a gas reservoir in Texas revealed two previously undetected seismic wave effects, recorded 2,000 ft above the reservoir. The first effect is that the dominant late phases on the recordings are tube waves, generated in the source well and converted into laterally propagating waves through gas/water saturated layers that then convert back to tube waves in the receiver well. This tube-wave train correlated with a multilayered reservoir zone structure, suggesting that the recorded wave field strongly depended on reservoir parameters. The second effect is that the recorded field is composed of multiple low-velocity tube waves. Modeling results suggest that imperfect cementation is the likely cause of this phenomenon.

ACCOMPLISHMENTS

How to interpret the strong late phases arriving in the 0.8–2.0-second interval during the crosshole seismic experiments is the key issue for this project. The relatively small travel time (0.2 seconds) for the direct P-wave arrivals suggests that the late phases belong to waves with long propagation paths and/or rather small velocities. This energy propagated in a different mode from the direct P-waves. Apparent velocities of the strongest phases around the 1-second arrival time were estimated to be in the 1,300–1,500 m/s range, which corresponds to propagating tube waves. High (90–100–200–220 Hz) and low (30–40–80–90 Hz) bandpass-filtered data indicate virtually the same results, which suggests negligibly low dispersion in the frequency band under consideration. The traces were cross–correlated with the first-arriving wave-train interval, which enabled measurement of the main peak travel times to better than 0.01-second accuracy. Measured travel times represent upward propagating waves of varying velocities. The almost perfect lateral homogeneity of the formation suggests that the wave propagation of late arrivals follows a three-legged path: The wave propagates downward as a regular tube wave, then converts into a horizontally propagating wave along some seismically conductive layer. After reaching the receiver well, the wave propagates upwards, splitting into a set of at least six waves of different velocities.

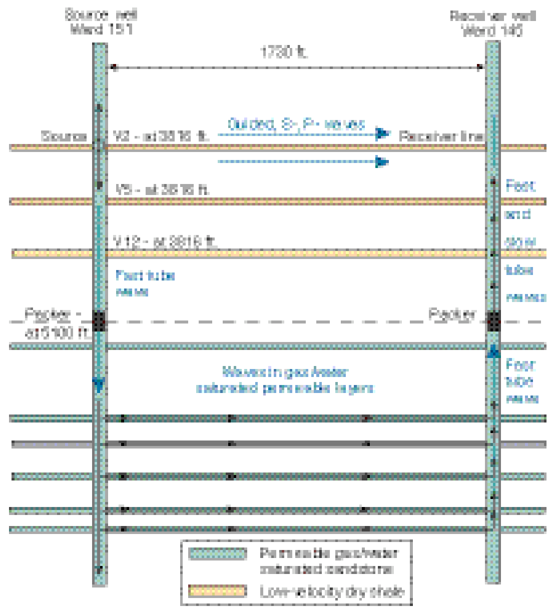

Figure 1. Crosswell experiment scheme and wave paths of the late arrivals

SIGNIFICANCE OF FINDINGS

Because reservoir waves should be affected by reservoir properties (i.e., porosity, permeability, fracture density, and orientation), monitoring based on use of these waves should allow the detection and interpretation of reservoir property changes near production boreholes. These effects can be used to develop a new and promising technology for the imaging and monitoring of underground gas, oil, and water reservoirs.

RELATED PUBLICATION

Korneev, V., J. Parra, and A. Bakulin, Tube-wave effects in crosswell seismic data at Stratton Field. SEG Expanded Abstracts, 2005. Berkeley Lab Report LBNL-53006.

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