Tube-wave Effects in Cross-Well Seismic Data

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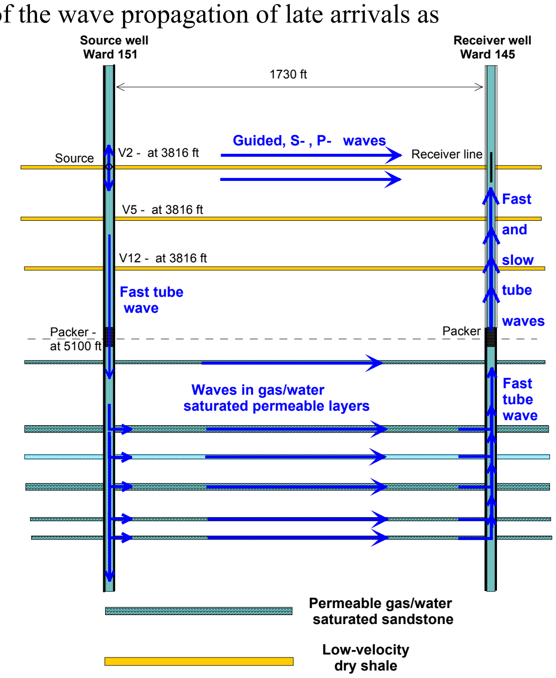
Objectives:
The main goal of this project is the developing new technology, which will improve the quality and resolution of seismic monitoring of natural underground reservoirs. The main innovative part of this technology includes use of tube waves as primary signal-carries, which will provide relatively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

Approach:

Tube waves are traditionally regarded as a source of high amplitude noise in borehole seismic data and much effort typically goes into their suppression and elimination from recordings. Tube waves have very large amplitudes and can propagate long distances without substantial decay. A tube wave is an interface wave for a cylindrical interface between two media, typically a borehole fluid and surrounding elastic rock. The analysis of crosswell seismic data for a gas reservoir in Texas revealed two newly detected seismic wave effects, recorded 2000 feet above the reservoir. The first is that the dominant late phases on the records are the tube waves generated in the source well and later converted into laterally propagating waves through the reservoir in gas/water saturated layers, which convert back to tube-waves in the receiver well. The tube-wave train showed good correlation with multilayered reservoir zone structure, suggesting that the recorded wave field has strong dependence on the reservoir parameters. The second effect is that the recorded field is composed of multiple low-velocity tube-waves. The modeling results suggest that imperfect cementation is the likely cause of this phenomenon.

Accomplishments: The interpretation of the strong late phases arriving in the 0.8–2.0 s interval during cross-hole seismic experiment are the main is the subject of this project. The relatively small travel time (0.2s) 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 was clearly elsewhere while the direct P- waves were arriving at 0.2 s. The apparent velocities of the strongest phases around the 1 s arrival time were estimated to be in the 1300-1500 m/s range, which corresponds to propagating tube waves. The traces were cross–correlated with the corresponding first arriving wavetrain interval, which allowed the measurement of the main peak traveltimes with better than 0.01 s accuracy. The high (90-100-200-220 Hz) and low (30-40-80-90 Hz) band-pass filtered data reveal practically the same results, which suggests negligibly low dispersion in the frequency band under consideration. The measured travel times for the strongest central peaks and represent upward propagating waves of varying velocities. The almost perfect lateral homogeneity of the formation permits the interpretation of the wave propagation of late arrivals as consisting of three-leg paths. The wave propagates downward as a regular tube wave, then converts into a horizontally propagating wave along some seismically conductive layer and after reaching the receiver well it propagates upwards, splitting into a set of at least six waves of different velocities at packer depth.

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 for the development of new and promising technology for the imaging and monitoring of underground gas, oil and water reservoirs.



Valeri Korneev, Jorge Parra, and Andrey Bakulin, 2005, Tube-wave Effects in Cross-Well Seismic Data at Stratton Field, SEG Expanded Abstracts

Figure. Cross-well experiment scheme and wave paths of the late arrivals.