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HIGH RESOLUTION VSP AS A TOOL FOR LOG DATA EXTRAPOLATION BENEATH AND AWAY FROM THE WELL

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Vertical seismic profiling proposed and developed by E.I. Galperin more than thirty years ago has become applieable to many exploration problems especially in oil and gas prospecting.

There are two leading technologies for investigation of oil and gas bearing reservoirs - surface seismics and logging. The variety of log methods is in general an adequate tool to determine the parameters of reservoirs penetrated by the well with necessary resolution. Surface seismic prospecting produce the 3D image of productive layers but its resolution is two orders of magnitude lower than achieved by logging. This limitation as well as different measurement schemes are the main causes for inadequate reconstruction of reservoir images by interpolation and extrapolation of detailed log data in discrete points by means of 3D surface seismic.

Vertical seismic prospecting combines the advantages of detailed downhole observations and surface 2D positioning of shot points to produce 3D images of productive layers. Some developments in VSP software and field VSP geometry are discussed below. These developments aim to provide application of high resolution VSP as a tool for log data extrapolation beneath and away from the well.

High resolution VSP investigation of borehole is called VSP-LOG and includes application of multipoint downhole tool, replaced on specified intervals, equal to integer part of distance between geophones.

Time shifts and amplitude gradients are measured with high accuracy after removal of reflection events calculated from log data. The resolution achieved may be one to several meters and data obtained on one side may be directly correlated to log data. On the other hand, this data correspond to seismic wavefields. The high resolution in this approach does not depend directly on frequency band, but is based on space sampling along the well.

This is not applicable to the problem of log extrapolation beneath the bottom of a well and away from the well. The first problem to be solved here is widening the frequency bend. The approach applied is optimal deconvolution based on estimation of signal power spectrum, noise power spectrum and reflection series power spectrum from VSP records on the first stage. The spectrum is smoothed with not over 3db variations in the range from 8Hz to 200-250Hz for real data.

The next stage is analytical continuation of spectra based on one-sided property of VSP records. Restoration of low (up to zero) and high frequencies gives the opportunity to obtain high resolution inversion for interval below the bottomhole.

If signal-to-noise ratio is high enough, the predicted acoustic impedances may be comparable to log data.

For offset VSP data the same approach to frequency resolution is applied. The next problems to be solved for image reconstruction are corrections for acoustic impedance in observation point, refraction, reflection, absorption, angle of incidence, spherical divergence and migration of restored amplitudes to the true reflection points in predetermined model.

VSP-CDP stack or migration procedure, taking into account all these corrections with following inversion, produce high resolution image of the media adjusted to log data in the well through VSP-LOG.

The case history illustrates application of this approach to accurate delineation of reef boundary to the Kokdumalak oil field in Uzbekistan. VSP-CDP cross section illuminates small fragment from 0 to 175m away from the well. About three times higher frequency and lateral resolution compared to surface CDP cross section give rise to detailed interpretation of anhidryte lenses and boundary of reef body.