DGMK/ÖGEW-Frühjahrstagung, Fachbereich Aufsuchung und Gewinnung
Celle, 5./6. April 2017

Imaging of geologic structures away from the borehole with acoustic logging data

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Abstract

Over the years, the primary application of borehole acoustic logging was to provide the compressional and shear wave slowness of the surrounding formation. Thanks to the emergence of modern borehole acoustic array tools, a variety of new applications, such as single-well imaging (SWI), has been developed. SWI uses conventional acoustic waveform data to produce high-resolution images of geologic structures up to tens of meters away from the borehole. This technique has generated significant interest because it can provide valuable information about natural fracture systems, and detect sub-seismic scale faults and bedding planes. Furthermore, in contrast to standard resistivity and acoustic borehole-wall imaging devices, SWI can detect small-scale features including those that do not intersect the borehole.

In general, the acoustic (monopole/dipole) transmitter generates two types of waves: 1) strong direct waves, which propagate along the borehole wall; 2) body waves, which radiate away from the borehole into the formation. When an incident body wave encounters a change in acoustic impedance (e.g., fracture, bedding plane), it can be reflected back and recorded with the receiver array, enabling that structure to be imaged. The final reflection image allows to determine the continuity and the dip of geologic structures, it also measures their azimuth, provided that the directional cross-dipole transmitter is used.

Many challenges are associated with single-well imaging, which make this application very demanding in terms of data processing. First, acoustic waveform data are dominated by strong direct waves that may have amplitudes several orders of magnitude higher than the reflected waves. Consequently, specific data processing techniques are required to enhance the reflection data and suppress the direct waves. In addition, the few receivers in an array and the limited acquisition aperture (total length of the array of receivers is approximately one meter), present an important challenge for standard migration algorithms and leads to low-resolution images. To overcome some of these problems, we propose a recently developed coherence-based migration (CBM), which is a focusing extension of the standard Kirchhoff-type migration. CBM can effectively reduce migration artifacts and random, uncorrelated noise, improving the image quality.