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"Fundamental Parameters Associated with Successful Hydraulic Fracturing – Means and Methods for a Better Understanding"
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Bringing Seismic Ideas to Acoustic Logging

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Abstract

As our industry transitions to a dependence on the more costly unconventional reservoirs, we strive to find new and more efficient ways to produce from those reservoirs. There has been much focus on drilling and hydraulic fracturing technologies, but what about identifying natural fractures? It is well known that natural fractures exist in the producing zones. It is also well known that only about twenty percent of the fraced area actually produces. If we, as an industry, were better able to identify the naturally fractured zones – we would be able to focus on that twenty percent of producing zones.

Currently, the industry uses acoustic logging or imaging to infer or find fractured zones. Unfortunately, however, the move to unconventional reservoirs has brought shortcomings in those techniques to the forefront. For images, widespread use of oil-based mud and the common practice of drilling high angle wells render image data mostly unusable. For shear wave anisotropy, fractures are simply inferred and, for many reasons, that inference cannot be relied on, particularly in unconventional reservoirs. Perhaps imaging and shear wave anisotropy need to make way for different processing techniques.

Furthermore, present day tools are only able to detect anisotropy when logged sections are more than five percent anisotropic, leaving the subtle fracture systems undetected. For this last issue, we need look no further than seismic and microseismic techniques for guidance. Due to issues with signal attenuation and a high signal-to-noise ratio, seismic has long used several techniques, such as stacking, to improve results and amplify anomalies.

In this discussion, we explore how we have adopted techniques from seismic and microseismic to provide useful and informative results on fractures creating a new processing technique for acoustic logging.

Current day techniques such as shear wave anisotropy and imaging still have applications in certain situations. However, they each have limitations. Fractures are anisotropic, so shear wave splitting can be an indication of fractures in subterranean formations; however, not all anisotropic formations are fractures. Therefore, use of shear wave anisotropy is not so much a definitive indicator of fractures, but a definitive indicator of anisotropic formations. Those formations may be fractures but may alternatively be other anisotropic, or seemingly anisotropic, formations. Furthermore, fractures, though anisotropic, can also exist in mildly anisotropic formations, which cannot be detected by the present-day tools using current methods since it is difficult to distinguish the subtle fracture patterns from the surrounding anisotropic media

using shear waves. Since fracture detection is the ultimate goal, given that fracture patterns indicate producing areas, a move towards a technique that actually identifies fractures, as opposed to simply inferring fractures, is logical.

The processing technique created by GeoBiz Technology, Inc. (GeoBiz) allows the industry to move towards a more direct method of characterizing fractures, since shear wave anisotropy does not allow for direct fracture detection. Although several industry tools, including LWD tools, collect sectored compressional waves, there has been little to no use for them in acoustic logging. However, looking at seismic research, work has been done to find fractures using compressional waves. Adapting the research that has been done to acoustic logging allows the industry to characterize fractures using compressional waves. Since tools already exist that collect necessary data, only the processing technique needed to be developed – which GeoBiz has done. The theory used to develop the GeoBiz processing technique is based on the theory that, across an open fracture, P-waves show a significant drop in energy. By mapping this drop in energy, fracture location and azimuth can be calculated. This technique has been tested in a number of wells and compared against core results. Test results show a match of approximately ninety percent between core data and log data, in both fractured and unfractured intervals (Fig. 1).

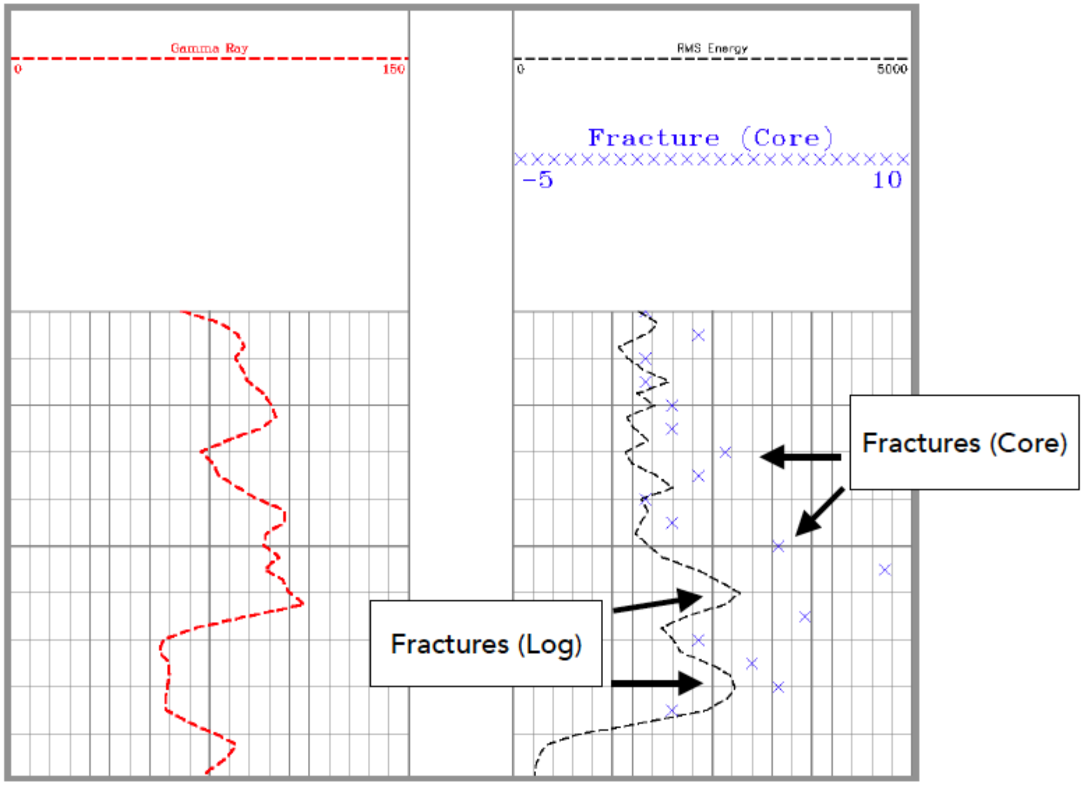

Figure 1: RMS Energy Distribution (right) across a Fractured Interval where fractures coincide w/a sharp drop in energy.

As noted, some tools already exist that collect sectored compressional waves. GeoBiz has found the use of these sectored waves is key in fracture characterization. The use of sectored waves allows for mapping the waveforms in a manner similar to what is currently done with shear waves, but with modified algorithms. Use of raw, sectored compressional waves is one of three key elements in the GeoBiz characterization method.

Although not mentioned in most publications, GeoBiz has found that RMS normalization is not only essential in processing sectored compressional waveforms, but in shear wave anisotropy as well. In both anisotropy and in the GeoBiz fracture detection method, four quadrants must be combined to compute RMS energies from 0-90 degrees. In order to combine these four quadrants, without normalization, we must assume the raw RMS energy output from all four quadrants is matched – unlikely and unrealistic. Therefore, the RMS energy must be normalized prior to combining. RMS normalization, then, is the second of the three key elements to the GeoBiz characterization method.

Although LWD tools provide some mapping capabilities, the signal-to-noise ratio is inadequate to properly identify subtle fracture patterns. The signal-to-noise ratio is also inadequate in traditional acoustic logging tools. To improve this ratio, we again adapt seismic techniques. In seismic data acquisition, stacking of data-gathers is routine. Until now, acoustic logging has found stacking techniques unnecessary. In order, however, to find natural fractures, which are the defining characteristic in a productive unconventional reservoir, the signal-to-noise ratio must be improved using a modified stacking technique. GeoBiz developed software to efficiently stack data-gathers, which allows us to deliver results within the time restrictions of operators in the field. For a tool with thirteen receivers, we can achieve a fifty-two fold stack. Stacking has led to a significant improvement in noise-to-signal ratio, enabling us to more confidently identify subtle variations in amplitude. This is the third key element to the GeoBiz characterization method.

In addition, the GeoBiz method allows us to not only identify fractures, but to also fully characterize the fracture patterns. Tests show the azimuth of fractures seen by both the imaging tool and by the sectored compressional tool match well (Fig. 3).

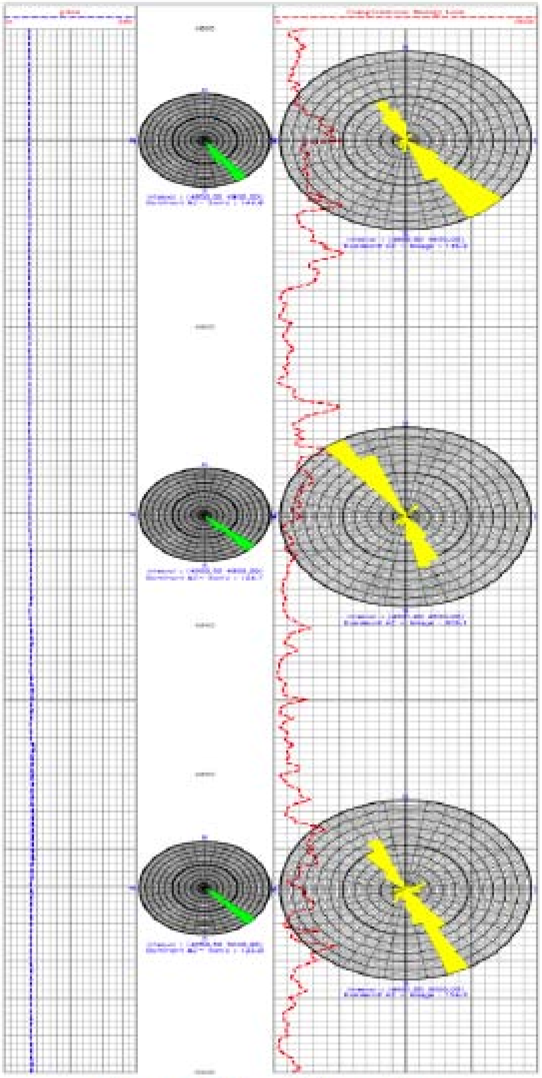

Figure 3: Azimuth Comparison Image (left) and P-Waves (right)

In summary, GeoBiz has developed a new technique with three key features that allow for more definitive characterization of fracture patterns in subterranean formations. The three key features are the use of sectored compressional waves to map energy in the formations, RMS normalization to achieve amplitude independence, and stacking of data-gathers in order to increase signal-to-noise ratio. This technique has shown remarkable accuracy when compared to core results in a shale play for both fracture identification and finding the azimuth of fractures.

References:

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