Chapter 8: How to quantify fracture intensity

Notes for Slides:

Slide 1: Fracture intensity is important but the challenge is to quantify the intensity so that it is of use in terms of comparison within and between reservoirs. Typically the way fracture systems are evaluated is by intensity, connectedness and the aperture of the system. Aperture studies are generally unreliable and often lead to poor decisions due to the number of assumptions that need to be made and the very large error bars on those assumptions.

Slide 2: Connectedness can be evaluated by plotting the orientation of fractures on a stereonet. It should be remembered that this is not a spatial representation but an angular relationship. With some assumptions the quality of the connectedness is represented by the half apical angle of the poles to fractures. A large angle would be more indicative of good connectedness.

Slide 3: Fractures are planar surfaces and as such require two numbers to describe their orientation (strike and dip). Many early studies used Rose Diagrams to describe the fracture orientation but failed to describe the dip and simply assumed that all fractures are vertical. This assumption is likely wrong and un-necessary as the stereonet is an effective tool that can describe bot the strike and the dip.

Slide 4: Proper analysis of fractures requires measuring the entire fracture surface area in a given volume of rock. Practically this is not possible. As a proxy scan line analysis is useful although there are some assumptions that go into the process. Wells are essentially scan lines so the scan line analysis for fractures can be applied directly to wells.

Slide 5&6: Scan lines are routinely used in well analysis. For fractures the position of the fracture and attributes of the fracture are recorded.

Slide 7: Fracture scan line along an outcrop of Cretaceous sandstones of the Frontier Formation in the Wind River basin of Wyoming. The issue is that the data need to be converted into a function that can be analyzed.

Slide 8: To analyze the data a smoothing or summing window is created. This window is scolled through the data and the original data which described a comb function is converted into a continuous function.

Slide 9-11: The size of the window will change the shape of the new function. The larger window will create greater smoothing and also greater amplitude. The curve may be standardized if wanted or the amplitudes can be preserved. In the case of fractures the

amplitudes are preserved under the assumption that increasing number of fractures reduce the friction to flow and as such is a true representation of the fractures ability to transmit fluids.

Slide 12&13: There are other methods to analyze the fracture patterns. In the case where a surface may be analyzed one can use a smoothing circle rather than a smoothing window. This process leads to some interesting results as vertical permeability barriers are exposed within a consistent sandstone section.

Slide 14: The entire Blue Draw outcrop fracture pattern within the Frontier Formation with a 10 metre summing window. The summing window creates a smoothly varying wave form, which can be further analyzed using Fourier Transforms.

Slide 15: A Fourier Transform converts a spatial sequence (or time sequence) into a function of Amplitude and Phase compared to Frequency. A spike is defined as the sum of all frequencies of equal amplitude with zero phase (the central peaks align). As the function deviates from a single peak the amplitudes and phases for the different frequencies differ. Any continuous series has a unique Fourier expression and as such the function can be looked at as swarms with some degree of repeatability.

Slide 16&17: The Fourier Analysis of the Blue Draw Fracture 10 metre summing window. The horizontal access is spatial frequency. The inverse of spatial frequency is wavelength such that the high amplitude at 0.004 corresponds to a 250 metre wavelength. This wavelength is a predictor of fracture swarms occurring every 250 metres. This is an important number as the length of optimal horizontal well lengths can be predicted. There are other peaks as well and the amplitude of the peaks become important in terms of frac stages and optimal wellbore stimulation design. A comment on phase; phase is important and likely indicating insight into the system. Fractures are considered to be causal events (meaning no negative spatial distances). Causal events have minimum phase and can be analyzed by minimum phase assumptions. The issue with this assumption is that the event is singular but that is not a safe assumption in fracture studies as the fracture pattern is likely the product of an extended episodic failure event. As such the phase considerations are under-constrained and of limited value.

Slide 18: The outcrop is divided by several normal faults. These faults can be used as domain boundaries and as such each domain may be separately analyzed.

Slide 19: The Fourier analysis of a single domain may not be sampled adequately to identify specific peaks. Most of the domains are less than 250 metres in length and as such do not show the peak. However, the area under the curve is the sum of all the amplitudes of the discrete fracture frequencies (wavelengths) and is a proxy for the fracture strain energy within that domain. The total fracture strain energy is the average fracture intensity for that domain.

Slide 20&21: In plotting the fracture intensity (normalized for differing lengths) for each domain there is an interesting pattern showing a decrease in the fracture intensity with distance from the mapped strike-slip faults. The conclusion is that the fracture intensity is controlled by the strike slip system.

Slide 22: In the absence of image logs it is still possible to gauge the fracture intensity by using cuttings. Specific features in the cuttings are indicators of fractures and can be quantified to create a fracture intensity curve

Slide 23: Fracture analysis from cutting on a horizontal well from the Horn River Basin (NEBC)

Slide 24: Another application of using Fourier analysis can be done on map images, which are particularly useful with seismic attributes.

Slide 25: A curvature surface may be analysed using a k_x vs. k_y transform. A technique that allows comparison of the spatial frequency in the x-direction to the spatial frequencies in the y-direction. This technique is used to find linear events on surfaces and the deviation from linear may also be approximated.

Slide 26: The results allow s for the comparison of linear events (fractures or faults in the case of curvature data) to gauge the dispersal angles and the relative amplitude.