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Hydraulic Fracture Geometries in Laminated Rocks when Initiated from Horizontal Wells Drilled in Tectonically Stressed Environments

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SUMMARY

In many countries where initial organic shale assessments are being undertaken the stress regime is compressional. This differs greatly from what is encountered in North America where an extensional geomechanical setting most commonly exists. In compressional settings the hydraulic fractures can propagate much differently than in relaxed basins. Hydraulic fractures generated from horizontal wells will initiate horizontally and may stay horizontal once away from the well because of the highly laminated nature of organic shales. Such a fracture geometry will greatly impact well performance in an adverse manner because vertical permeability in laminated shales is nil. Consequently, successful organic shale development may be compromised in such environments.

Introduction

In many countries where unconventional resources are now being explored the structural setting is compressional: overburden is the intermediate or lowest principle stress. Fracture geometries can be much different for horizontal wells drilled in this environment as compared to the extensional environment prevalent in North America. Axial, horizontal fractures will form at the well in most cases in this setting. Once away from the wellbore these fractures should theoretically reorient to vertical when the overburden is the intermediate principle stress, or remain horizontal when the overburden is the lowest principle stress.

Because of their depositional environment, organic shales are pervasively highly laminated. In many cases they are extremely over pressured with the resulting effective principle stresses quite close together. As the principle stresses equilibrate textural features can greatly influence hydraulic fracture geometries with resulting dimensions that are much different than historically seen in conventional reservoirs.

For organic shales in a compressional environment a significant component of the hydraulic fracture system can remain horizontal even once away from the near-well stress concentration. A series of stacked horizontal fractures along bedding planes can occur for wells that are not perfectly aligned with the beds. Fracturing pressures will be high and proppant placement will be difficult in such a case. Consequently fracture conductivity may be compromised. This can result in organic shales not being effectively stimulated as would otherwise occur in the extensional structural setting common to North America. As the unconventional industry migrates from North America to the rest of the world these geomechanical attributes must be taken into consideration, else well performance may be much worse than what is indicated by organic shale petrophysics.

Theory

Fracture initiation at a well is driven by the tangential effective stresses surrounding the hole. For a well drilled in the direction of minimum horizontal stress the tangential stresses are controlled by the overburden and the maximum horizontal stress. The fracture will propagate in the direction of the highest tangential stress until it grows beyond the near-well stress concentration at which time it normally orients to be normal to the least principle far-field stress. But in over pressured reservoirs, which are common in organic shales, the effective stresses can be close to each other. In such a case textural features of the rock will dominate fracture geometry.

When drilling a horizontal well in the direction of the minimum horizontal stress in a strike-slip setting the near-well fracture will be axial and horizontal with the well. Because of anisotropic mechanical properties in laminated source rocks fractures that initiate horizontally can continue to propagate horizontally one away from the well, even though the minimum principle stress is vertical. Horizontal fractures will not significantly contribute to well performance because the vertical permeability of organic shales is insignificant, owing to the thin argillaceous intervals which are almost always encountered.

Production has not been adversely affected in North America because the structural setting is extensional in almost all cases where organic shales are being developed. In this setting hydraulic fractures from horizontal wells will initiate vertically and are much more likely to propagate vertically through the organic shale. But as exploration of shales is undertaken in basins in a compressional setting well performance may be far below that encountered in an extensional environment, even when the petrophysical properties of the shales are similar.

Figure 1 Left Image: A wireline resistivity image of a highly laminated organic shale. The drilling induced fractures dilate on bedding interfaces of significant resistivity contrast. Right Image: An estimate of unconfined compressive strength (UCS) as determined from a scratch test along the slabbed core's surface. The large variation in UCS is indicative of the variation in mechanical properties in organic shale beds that can influence hydraulic fracture geometries. (Unit of measure is feet for both images)

Conclusions

Hydraulic fractures initiated in a compressional environment may not as effectively stimulate organic shales as occurs in extensional structural settings such as most of North America.

Well performance can be significantly compromised when a large component of the fracture system is horizontal.

These geomechanical and lithological features may make organic shale development problematic. This has significant implications for the development of organic shales in compressional settings.

References

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