Brittleness and Fracability in Stimulating Shale Gas Reservoirs

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Summary

In the present study of stimulating unconventional shale reservoirs, brittleness index profiling along the reservoir payzone to identify the most desirable perforated intervals has become a common practice. The profile is considered as an indispensable geomechanics component in the approaches in the petrophysical domain. However, this paper challenges the validity of the brittleness index profiling method. With objective review and sensible definition of brittleness used in the present petrophysical field to identify the desirable fracturing intervals, the paper presents the ambiguities of using brittleness to define the formation fracability, and points out that the formation brittleness can be unrelated to the formation fracability. As an alternative approach, this paper provides an effective method to define the most fracable formation intervals in designing the hydraulic fracturing in tight shale gas formations.

Content

With respect to brittleness, it is about the type of material and its related strength. In comparison with a ductile material under load, a brittle material has a relatively shorter plastic deformation and responds dominantly by the elastic deformation. With respect to fracability, it is about the rock failure under the ultimate rock strength in either a brittle or ductile formation. In comparison, the higher fracable formation should have smaller formation strength than the lower fracable formation. In consequence, it is not certain that the brittle formation is easier to fracture than the ductile formation since a brittle formation may have greater strength than a ductile formation even though the exceptions may exist.

More complications arise when evaluating the responses of subsurface formations at great depth than the formation types (e.g. brittle formation or ductile formation). Under this condition, the impact of confinement on the fracability cannot be ignored. In general, a formation subject to higher confinement pressure is more difficult to fracture as the formation strength is greater. Conversely, a formation subject to lower confinement pressure is easier to fracture since the formation strength is smaller.

In view of efficient stimulation of shale gas reservoirs, it is unclear whether we should choose the brittle interval or the ductile interval to fracture as the strength of either interval is unknown. However, it is apparent that we should choose the formation interval with a higher fracability, which is equivalent to the lower formation strength. Under similar confinements, the lower formation strength may be indicated by a smaller unconfined compressive strength (UCS). As a result, it is advisable that the most fracable interval is the one with lowest UCS.

When evaluating present technology, the formation brittleness should no longer be the associated subject matter as we are unclear about its role to improve the fracability of a tight formation. Disassociating the brittleness from fracability enables us to focus on identifying the true mechanisms for efficient fracturing of tight shale reservoirs.

Conclusions

Formation brittleness and ductility are not related to formation mechanical properties such as Young's modulus and Poisson's ratio, as commonly used in brittleness index profiling. Instead, formation brittleness and ductility are related to the rock strength such as unconfined compressive strength (UCS) or fracture toughness.

It is ambiguous to relate formation brittleness to formation fracability, since a brittle formation may have greater rock strength under higher confinement, making it more difficult to fracture, and vice versa.

The formation fracability is about the ultimate rock failure defined by the formation breakdown pressure. The breakdown pressure can be identified in unrestricted fracturing using the unconfined compressive strength (UCS) as a benchmark value. However, it is difficult or sometimes impossible to identify the breakdown pressure in restricted fracturing since the fracturing treatment is limited in size and is often localized, while the extended free fracture propagation is not apparent from the bottom hole pressure response. Under this condition, the formation fracability may be determined from the fracture toughness based dynamic fracturing process.

Disassociating formation brittleness from formation fracability allows us to correctly determine the most fracable formation intervals to perforate.

This presentation proposes an effective approach to select the desirable intervals to stimulate, i.e., select the weak spots determined from a formation UCS profile to establish the perforated intervals. The proposed method is supported by many early experimental studies.

References

Bai, M. (2016), Why are brittleness and fracability not equivalent in designing hydraulic fracturing in tight shale gas reservoirs, Petroleum, Vol. 2, 1-19, ISSN 2405-6561, SwPU, Elsevier.

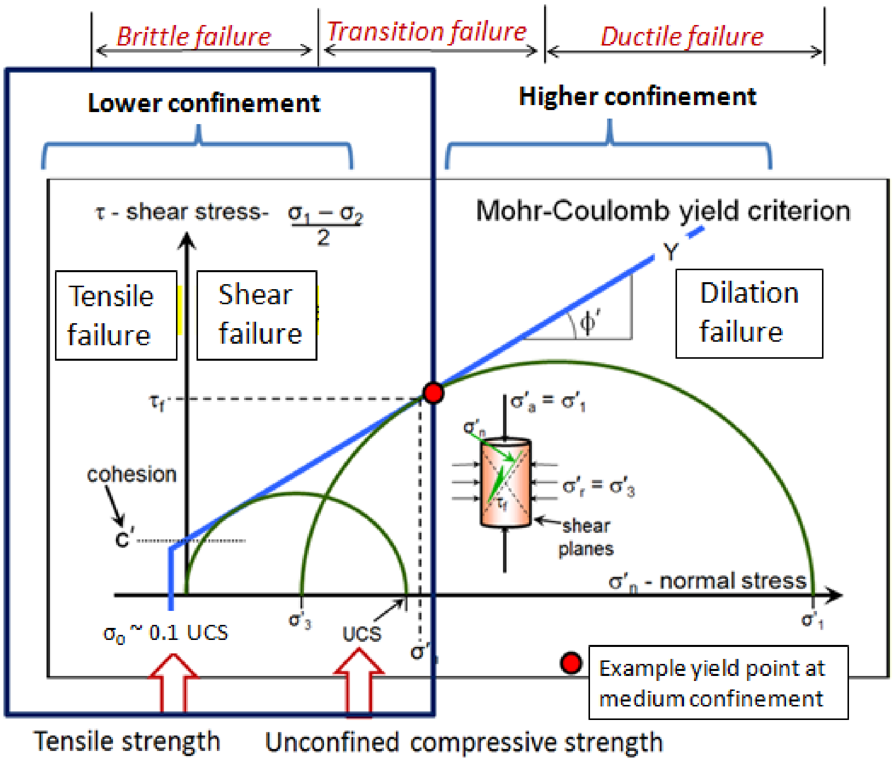

Figure 1 Example yield point is the cutoff value in the transition failure between brittle (lower confinement) and ductile (higher confinement) rock failures in a Mohr-Coulomb chart.