Fracture Potential of Challenging Rocks: From Initiation to Productive Stimulated Rock Volume*

Uno Mutlu[1], Jian Huang[1], Reza Safari[1], and Mojtaba Pordel Shahri[1]

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[1]Weatherford, Houston, TX, USA (ovunc.mutlu@weatherford.com)

Abstract

Fracture potential of challenging rocks determines the ability of a rock to create complex, extensive and highly connected fracture networks that can remain open during production. Prediction of a robust fracture potential is an important prerequisite for optimized stimulation design and maximized Productive Stimulated Rock Volume (P-SRV). However, fracture potential is not a material property. Contrary to the common belief, "ability to fracture, brittleness, fracture efficiency, fracture potential" are not characteristic properties but rather a rate and stress dependent material "behavior" for a given rock type.

Introduction

In order to fully characterize this behaviour and optimize stimulation design: key attributes that control fracture initiation, propagation, opening and closure need to be identified, their relative impact/weight(s) need to be quantified and integrated. For example, integration of ranked/weighted log based fracture attributes (Figure 1a) can provide a quick look/screening analysis to identify -near wellbore zones- with high vs. low fracture potential (Figure 1b). Attributes can include a combination of basic elastic properties, unconfined compressive strength, mineral content, stress anisotropy, formation anisotropy, cohesion, friction angle, in-situ fracture toughness and natural fracture/fault network reactivation potential. This approach serves an as uplift to standard/single parameter predictions and can provide proxies for near wellbore fracture initiation and closure characteristics (Figure 1c).

Methods

Integrated quick look analysis can be used as a semi-qualitative screening tool for predicting hydraulic fracture potential and stage design. In order to "quantify" the impact of key parameters on fracture potential and complexity, extensive sensitivity analyses should be performed within the framework of advanced 3D geomechanical models. These models utilize rate and pressure dependent constitutive models to simulate material failure behavior under a variety of loading/rate conditions and for geologically plausible scenarios. Simulations couple fluid flow with mechanical deformation to predict fracture initiation, growth and coalescence away from the wellbore. These advanced models can capture different modes of rock failure (tensile, shear and compactive), ductile to brittle transition, fracture coalescence, branching/complexity as well as fracture closure risk during production (see Figure 2). Therefore model results provide important clues to understand which fractures (under what conditions) would contribute to production and P-SRV.

Discussion

Hydraulic fracture potential and characteristics are also affected by fracture interactions. Therefore, P-SRV is not only a function of rate and pressure dependent material behavior, intrinsic anisotropy, stress state, etc., but is also controlled by natural fracture reactivation and/or hydraulic-natural fracture interactions. Recent advances in computational geomechanics allow analysis of complex fracture network growth and fracture reactivation/interaction phenomena at reservoir scale: introducing a new generation of models (Figure 3a). These models can capture multiple hydraulic fracture propagation phenomena and interaction(s) with the pre-existing discrete fracture network (DFN). As the fracture network reacts to stimulation and complexity evolves, hydraulic fractures can curve, arrest or crosscut natural fractures if the stress state and DFN properties (i.e. interface strength, cement fill, orientation, spacing, height…) dictate that they should. Several outputs can be generated from these models such as pressure, synthetic microseismicity and conductivity maps (Figure 3b). An important observation is that synthetic microseismicity does not necessarily correlate with fracture conductivity maps and therefore can overestimate/underestimate P-SRV. These next-generation models, (i.e. within the framework of an integrated workflow and microseismic field data calibration), can be utilized to constrain/optimize P-SRV for reservoir/production simulations or infill/new well design (Figure 3c).

Summary

In this study, we present integrated quick look analysis, advanced geomechanical simulations and next generation models for evaluating fracture potential and P-SRV in permeability challenged rocks. Fracture potential is not a material property but rather a complex function of reservoir and geomechanical parameters. In quick look analysis, relative impact of each parameter on the resulting fracture patterns and fracture efficiency should be considered and then integrated to identify fracture sweet spots. We utilize advanced geomechanical models (based on a set of parameters included in the quick look analysis) and incorporate rate/pressure dependent constitutive models to further quantify fracture potential/characteristics away from the wellbore. We show that fracture potential is not only dictated by the complexity/extent of the hydraulic fractures but also risk of fracture closure, proppant embedment and crushing should be included in the analysis for a complete evaluation of this potential. Discrete Fracture Networks (DFN(s)) and their interaction with propagating hydraulic fractures can have a significant impact on the resulting fracture patterns. Next generation fracture models, when coupled/calibrated with field observed microseismicity, can help distinguish between dry-SRV vs. productive-SRV and constrain reservoir simulations, infill/new well design.

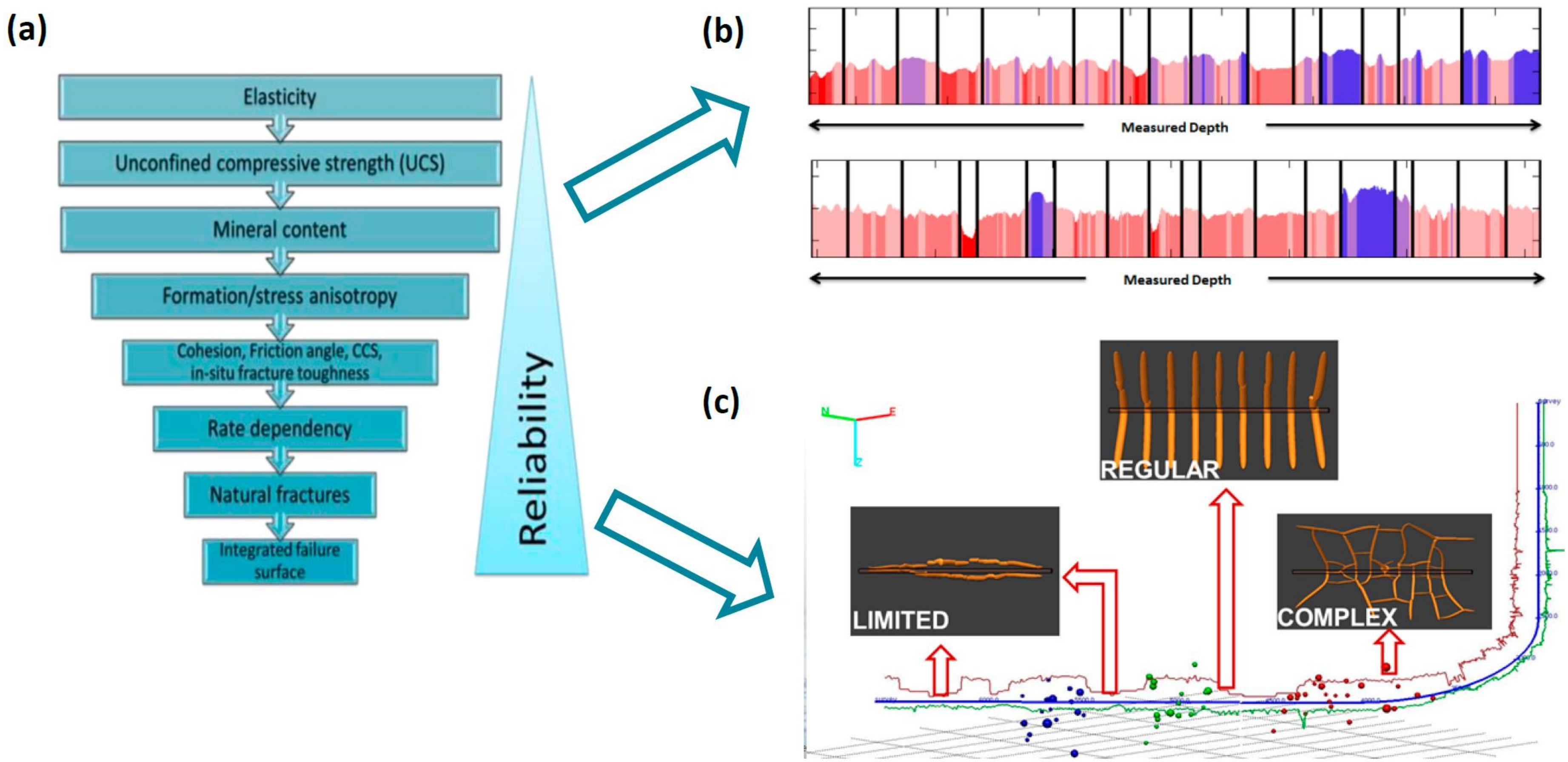

Figure 1. (a) Ranked/weighted attributes, (b) quick look analysis based on integrated attributes (i.e. cold colours indicate areas with high fracture potential), (c) fracture characteristics (regular, complex, limited).

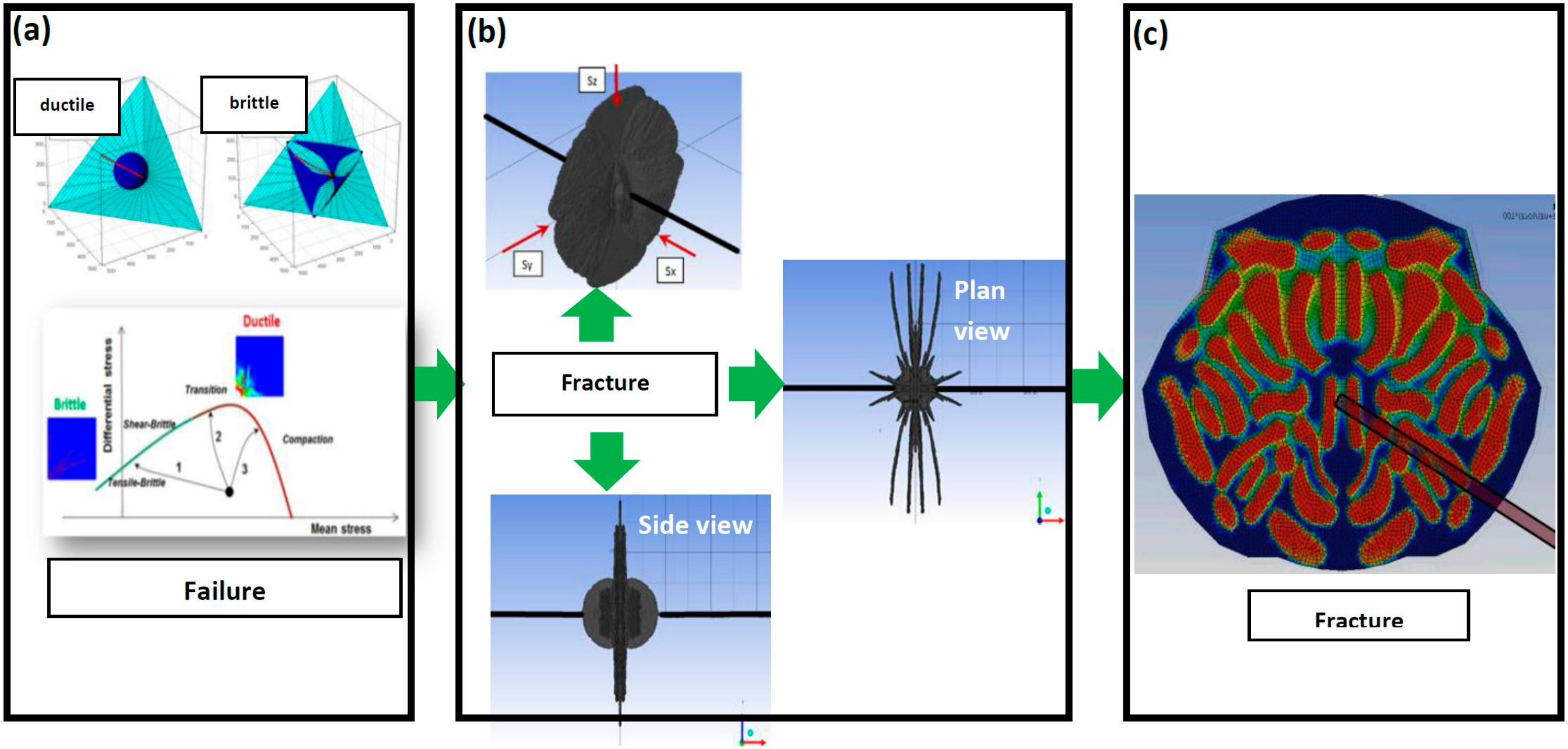

Figure 2. (a) Failure behaviour/surfaces, (b) fracture patterns, and (c) fracture closure, proppant embedment and crushing during production (warm colours indicate open fracture areas).

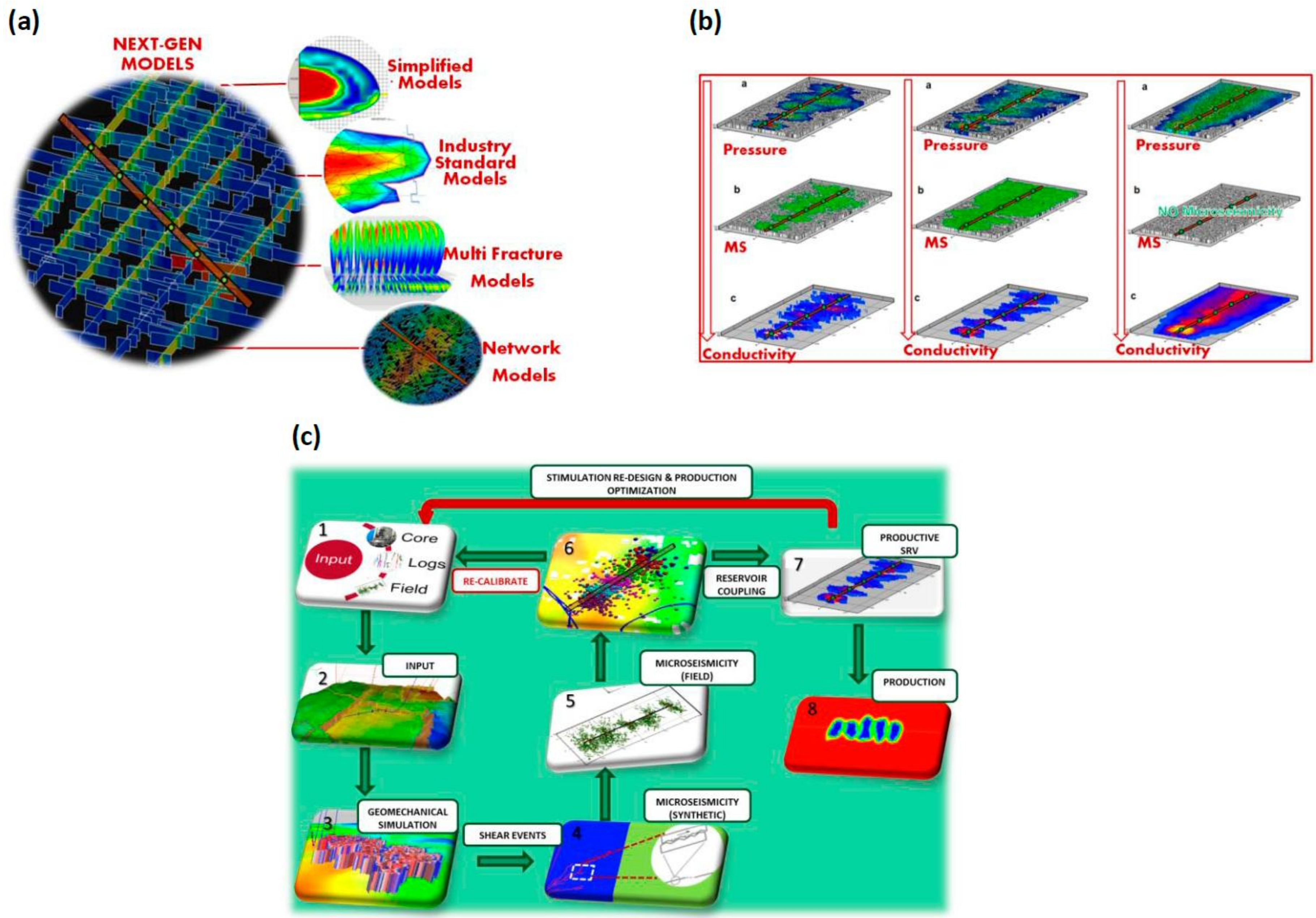

Figure 3. (a) Evolution of geomechanical models, (b) model outputs, and (c) workflow.