Abstract

Unconventional reservoirs represent a challenge in terms of production. In fact, they need advanced techniques such as horizontal well placement and hydraulic fracturing to be successfully exploited at economic rates. This work introduces the concepts of static and dynamic reservoir quality (RQ). Static RQ, related to formation storage, refers to a set of petrophysical parameters that characterize formation attitude to the development. Dynamic RQ refers to producibility and comprises a set of geomechanical parameters describing rock capability to be fractured; the term dynamic RQ is used in place of the more used completion quality and it differs from the latter because it does not consider the in situ stress data. The different features defined by static and dynamic RQs allow to recognize the “so called” productive sweet spots. In particular, productive sweet spots correspond to those intervals with good static and dynamic RQs.

The workflow developed in this study is focused on the identification of producible intervals in unconventional reservoirs by means of lithologic and geomechanical facies classification. A set of lithologic facies is initially created by applying a clustering technique on core data; those lithologic facies are then extended to the logged interval and characterized in terms of static RQ. The same approach has been adopted to describe geomechanical facies. In this work, Young’s modulus is directly used as brittleness indicator to characterize geomechanical facies for dynamic RQ description. Sweet spot identification is the outcome of the integration of the static RQ and the dynamic RQ. The workflow is applied to the Barnett Shale Formation; the logged interval is classified with four lithologic facies (LF) and five geomechanical facies (GF). The best interval in terms of static and dynamic RQs is identified in the upper and middle sections of the Lower Barnett, defining the productive sweet spot. At the end, LF and GF are linked to seismic facies probability volumes and Young’s modulus derived from elastic inversion of surface seismic. Seismic-driven geostatistical realization of LF and GF leads to estimate of static and dynamic RQs volumes that, in turn, are combined into volumes of productive and non-productive facies. This methodology represents an early step in the building of reliable and predictive models for gas shale with positive impact on productive sweet spot location, asset production and overall value.
Searching for Sweet Spot: Multi-Facies and Multi-Scale Approach for Gas Shale Reservoir Characterization

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**Introduction: the Barnett Shale formation**

**Methodology: a three-step workflow**

1) Static Reservoir Quality (Productivity)
   - Core and log data related to lithology and fluid content

2) Dynamic Reservoir Quality (Frack-ability)
   - Core and/or log properties that affect geomechanical behavior

3) Productive Sweet Spot
   - Integration of Static and Dynamic Reservoir Quality

**Application: searching for sweet spot**

**Improvement: from log to seismic-driven model**

**Legend**

- Core Facies (CF) as driver
- Raw logs (lithological)
- Log-derived dynamic properties
- Geomechanical Facies (GF)
- Young’s modulus

**Reservoir properties:**
- Porosity: 4% - 10%
- Permeability: 10⁻¹ mD = 10⁻⁷ mD
- Organic content (TOC): 2% - 7%
- GIP: 50 = 200 kg/m³

**Interval 1
Interval 7
Interval 2
Interval 3
Interval 4
Interval 5
Interval 6**

**AVO/AVA Seismic Inversion**
- Pressure impedance
- Shear impedance
- Density

**Input:**
- Log Facies (LF)
- Geomechanical Facies (GF)

**Input:**
- Log Facies (LF)
- Log-derived dynamic properties
- Geomechanical Facies (GF)
- Young’s modulus

**Legend**

- LF: Log Facies
- GF: Geomechanical Facies
- GF1: Geomechanical Facies 1
- GF2: Geomechanical Facies 2
- GF3: Geomechanical Facies 3
- GF4: Geomechanical Facies 4
- GF5: Geomechanical Facies 5

**GF5**

**GF4**

**GF3**

**GF2**

**GF1**

**Legend**

- A = B
- E = F
- (A + B) = C
- (A + B + C) = D
- (A + B + C + D) = (E + F)

**Statistical method that looks for similarity/dissimilarity between data points in order to group them into classes**

- Euclidean Distance as a measure of dissimilarity
- Three main phases:
  1. Classification (Hart’s hierarchical method)
  2. Discrimination (F-means clustering)
  3. Verification (Contingency analysis)

**Hierarchical grouping:**

- Increasing from GF1 to GF5

**Barnett Shale formation**

- Location: Fort Worth Basin (Texas)
- Age: Mississippian
- Area/Thickness: 5000 m²/100 ft = 600 ft

**Improvement: from log to seismic-driven model**

1) Static Reservoir Quality (Productivity)
   - Log Facies Probability (LFP) from LF seismic upscaling
   - Probability Density Function (PDF) computation
   - Discrimination Facies Probability (DFP) volume generation
   - Posterior SFP calibration with prior LFP
   - Calibrated SFP as soft constraint for LF modeling

2) Dynamic Reservoir Quality (Frack-ability)
   - Geomechanical Facies Probability (GFP) from GF seismic upscaling
   - Calibration with Young’s modulus from AVO Elastic Inversion
   - Young’s modulus as driver for Dynamic Reservoir Quality distribution

3) Productive Sweet Spot
   - 3D realization of Static Reservoir Quality
   - 3D realization of Dynamic Reservoir Quality
   - Productive sweet spot identification at grid scale