## Contents

**Preface**  

**Part I  Physical Properties of Unconventional Reservoirs**  

1  Introduction  

Unconventional Resources  6  
Types of Unconventional Reservoirs  9  
Recovery Factors and Production Rates  17  
Horizontal Drilling and Multi-Stage Hydraulic Fracturing  21  

2  Composition, Fabric, Elastic Properties and Anisotropy  31  

Composition and Fabric  31  
Elastic Properties  41  
Elastic Anisotropy  50  
Poroelasticity  53  
Estimating Elastic Properties from Geophysical Data  56  

3  Strength and Ductility  65  

Rock Strength  65  
Time-Dependent Deformation (Creep)  69  
Stress and Strain Partitioning  73  
Modeling Time-Dependent Deformation  76  
Estimating In Situ Differential Stress from Viscoelastic Properties  80  
Brittleness and Stress Magnitudes  84  

4  Frictional Properties  91  

Fault Strength and Stress Magnitudes  92  
Rock Friction  95  
Frictional Strength and Stability  101  
Implications for Induced Shear Slip during Hydraulic Stimulation  111
## Table of Contents

### Part I \( \text{Unconventional Reservoir Geomechanics} \)

5 \hspace{1em} Pore Networks and Pore Fluids
- Matrix Porosity
- Matrix Pore Networks
- In Situ Pore Fluids

6 \hspace{1em} Flow and Sorption
- Matrix Flow
- Permeability
- Sorption

7 \hspace{1em} Stress, Pore Pressure, Fractures and Faults
- State of Stress in US Unconventional Reservoirs
- Measuring Stress Orientation and Magnitude
- Pore Pressure in Unconventional Reservoirs
- Fractures and Faults in Unconventional Reservoirs
- Utilizing 3D Seismic Data to Map Fault zones and Fractures

### Part II \( \text{Stimulating Production from Unconventional Reservoirs} \)

8 \hspace{1em} Horizontal Drilling and Multi-Stage Hydraulic Fracturing
- Horizontal Drilling
- Multi-Stage Hydraulic Fracturing
- Fracturing Fluids and Proppants

9 \hspace{1em} Reservoir Seismology
- Microseismic Monitoring during Reservoir Stimulation
- Seismic Wave Radiation
- Earthquake Source Parameters and Scaling Relationships
- Earthquake Statistics
- Locating Microearthquakes

10 \hspace{1em} Induced Shear Slip during Hydraulic Fracturing
- Shear Stimulation and Production
- Coulomb Faulting and Slip on Poorly Oriented Fracture and Fault Planes
- Shear Slip and Permeability

11 \hspace{1em} Geomechanics and Stimulation Optimization
- Landing Zones
- Optimizing Completions I: Field Tests and Reservoir Simulation
- Vertical Hydraulic Fracture Growth
# Table of Contents

**Optimizing Completions II: Reservoir Simulation and 3D Geomechanics** 334
- Viscoplastic Stress Relaxation and Varying Stress Magnitudes with Depth 339
- Targeting Geomechanical Sweet Spots: Fractures, Faults and Pore Pressure 344

## 12 Production and Depletion

- Production Decline Curves and One-Dimensional Flow 345
- Using Microseismicity to Estimate Total Fracture Area 346
- Evolution of a Shear Fracture Network 349
- Matrix Damage and Permeability Enhancement 353
- Seismic and Aseismic Fault Slip 358
- Depletion of Ultra-Low Permeability Formations with High Permeability Fractures 359
- The Frac Hit Phenomenon and Well-to-Well Communication 360
- Modeling Poroelastic Stress Changes 362

## Part III Environmental Impacts and Induced Seismicity

### 13 Environmental Impacts and Induced Seismicity

- Overview of Environmental Issues 375
- Induced Seismicity 378

### 14 Managing the Risk of Injection-Induced Seismicity

- Avoiding Injection Near Potentially Active Faults 377
- Estimation of Fault Slip Potential in the Permian and Fort Worth Basins 389
- Risk Management and Traffic Light Systems 406
- Utilizing Seismogenic Index Models to Manage Produced Water Injection 415
- Site Characterization Risk Frameworks 422

*References* 426

*Index* 434

© in this web service Cambridge University Press  www.cambridge.org