## Contents

**Preface**

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ix</td>
</tr>
</tbody>
</table>

### 1 Basic Pressure Concepts and Definitions

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Basic Concepts</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Pore Pressure Gradient</td>
<td>5</td>
</tr>
<tr>
<td>1.4 Overburden Stress</td>
<td>7</td>
</tr>
<tr>
<td>1.5 Effective Vertical Stress and Terzaghi’s Law</td>
<td>9</td>
</tr>
<tr>
<td>1.6 Formation Pressure</td>
<td>12</td>
</tr>
<tr>
<td>1.7 Casing Design</td>
<td>18</td>
</tr>
<tr>
<td>1.8 Importance of Geopressure</td>
<td>19</td>
</tr>
</tbody>
</table>

### 2 Basic Continuum Mechanics and Its Relevance to Geopressure

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Introduction</td>
<td>32</td>
</tr>
<tr>
<td>2.2 Stresses and Forces in a Continuum</td>
<td>32</td>
</tr>
<tr>
<td>2.3 Deformation and Strain</td>
<td>39</td>
</tr>
<tr>
<td>2.4 Fundamental Laws of Continuum Mechanics</td>
<td>41</td>
</tr>
<tr>
<td>2.5 Hooke’s Law and Constitutive Equations</td>
<td>44</td>
</tr>
<tr>
<td>2.6 Elasticity, Stress Path, and Rock Mechanics</td>
<td>54</td>
</tr>
<tr>
<td>2.7 Poroelasticity</td>
<td>56</td>
</tr>
<tr>
<td>2.8 Linear Stress–Strain Formulation for Poroelastic Media (Static Poroelasticity)</td>
<td>59</td>
</tr>
<tr>
<td>2.9 Mechanical Compaction from Plastic–Poroelastic Deformation Principles</td>
<td>65</td>
</tr>
<tr>
<td>2.10 Fracture Mechanics and Hydraulic Fracturing</td>
<td>71</td>
</tr>
<tr>
<td>2.11 Rock Physics Basis for Detection and Estimation of Geopressure</td>
<td>75</td>
</tr>
</tbody>
</table>

### 3 Mechanisms of Geopressure

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Introduction</td>
<td>84</td>
</tr>
<tr>
<td>3.2 Stress Related: Vertical (Compaction Disequilibrium)</td>
<td>85</td>
</tr>
<tr>
<td>3.3 Stress Related: Lateral (Associated with Compaction Disequilibrium)</td>
<td>96</td>
</tr>
<tr>
<td>3.4 Chemical Diagenesis as a Geopressure Mechanism</td>
<td>97</td>
</tr>
<tr>
<td>3.5 Kerogen Conversion and Hydrocarbon Generation as Mechanisms of Geopressure</td>
<td>112</td>
</tr>
</tbody>
</table>
Table of Contents

3.6 Chemical Diagenesis due to Gypsum-to-Anhydrite Transformation 119
3.7 Charging through Subsurface Structures (Lateral Transfer of Fluids) 119
3.8 Hydrocarbon Buoyancy as a Cause of Overpressure 122
3.9 Hydraulic Head as a Cause of Overpressure (Erosion/Uplift, Elevation Related to Datum) 126
3.10 Aquathermal Pressuring as a Mechanism of Geopressure 127
3.11 Osmotic Pressure as a Source of Geopressure 128
3.12 Summary 128

4 Quantitative Geopressure Analysis Methods 130
4.1 Introduction 130
4.2 Normal Compaction Trends and Characteristics of Undercompacted Zones 133
4.3 Methods to Predict Geopressure 135
4.4 Pore Pressure Prediction in Carbonates (and Other Competent Rocks) Where Common Shale-Based Techniques Do Not Work 175
4.5 Measurement of Pore Pressure 180
4.6 Leak-Off Test, Extended Leak-Off Test, and Fracture Gradient 185
4.7 Subsalt Pore Pressure and Fracture Pressure 197
4.8 Overburden Stress Evaluation 200
4.9 Effect of Water Depth on Overburden and Fracture Pressure Gradients 209
4.10 Temperature Evaluation (Direct and Indirect Methods) 210
4.11 Summary 215

5 Seismic Methods to Predict and Detect Geopressure 218
5.1 Introduction 218
5.2 Measurements of Velocity 220
5.3 Seismic Velocity from Traveltime Analysis and Anisotropy 228
5.4 Seismic Velocity from Inversion 245
5.5 Summary: Seismic Velocity Analysis and Guidelines for Applications to Pore Pressure 277

6 Integrating Seismic Imaging, Rock Physics, and Geopressure 281
6.1 Introduction 281
6.2 Rock Physics Guided Velocity Modeling (RPGVM) with Reflection (CIP) Tomography for Pore Pressure Analysis 282
6.3 Example Applications of Rock Physics Guided Velocity Modeling for Geopressure and Imaging with CIP Tomography 291
6.4 Subsalt Pore Pressure Applications 297
6.5 Rock Physics Guided Velocity Modeling for Pore Pressure and Imaging with FWI 306
6.6 Summary 308
# Contents

## 7 Methods for Pore Pressure Detection: Well Logging and Drilling Parameters

- **7.1 Introduction** 310
- **7.2 Logging Tools** 311
- **7.3 Pore Pressure from Well Logging Methods** 313
- **7.4 Recommendations on Use of Wireline Logs for Pore Pressure Analysis** 327
- **7.5 Drilling Parameters for Pore Pressure Analysis** 329

## 8 Gravity and EM Field Methods Aiding Pore Pressure Prediction

- **8.1 Introduction** 338
- **8.2 Gravity Method** 339
- **8.3 Electromagnetic Method** 341
- **8.4 Joint Inversion** 343
- **8.5 Concluding Remarks** 347

## 9 Geopressure Detection and Prediction in Real Time

- **9.1 Introduction** 348
- **9.2 Strategy for Real-Time Update and Prediction Ahead of the Bit** 348
- **9.3 Pore Pressure Prediction Methods in Real-Time** 352
- **9.4 Seismic-While-Drilling Technology for Real-Time Pore Pressure Prediction** 356
- **9.5 Geopressure Prediction in Real-Time Using Basin Modeling** 365
- **9.6 Summary** 367

## 10 Geopressure Prediction Using Basin History Modeling

- **10.1 Introduction: Basin and Petroleum System Modeling** 368
- **10.2 Governing Equations for Mathematical Basin Modeling** 369
- **10.3 Basin Modeling: Compaction, Diagenesis, and Overpressure** 371
- **10.4 Basin Modeling in 3D** 389

## 11 Geohazard Prediction and Detection

- **11.1 Introduction: What Is Geohazard?** 392
- **11.2 Shallow-Flow-Sands (SWF)** 393
- **11.3 Shallow Gas as Geohazard** 411
- **11.4 Gas Hydrate as Geohazard** 414
- **11.5 Geohazard Mitigation (Dynamic Kill Drill or DKD Procedure)** 418
- **11.6 Recommendations for Detection of Geohazards** 419
- **11.7 Concluding Remarks** 420

## 12 Petroleum Geomechanics and the Role of Geopressure

- **12.1 Introduction** 421
- **12.2 Borehole Stability and Pore Pressure** 423
# Contents

12.3 Petroleum Geomechanics Modeling  
12.4 4D Geomechanics and 4D Earth Model Building  
12.5 Summary  

13 Guidelines for Best Practices: Geopressure Prediction and Analysis  
13.1 Introduction  
13.2 Subsurface Geological Habitat for Geopressure (Geology)  
13.3 Physics of Pore Pressure Generation (Models)  
13.4 Technology for Subsurface Prediction (Tools)  
13.5 Uncertainty Analysis  

14 Recent Advances in Geopressure Prediction and Detection Technology and the Road Ahead  
14.1 Introduction  
14.2 Seismic Technology  
14.3 Models That Relate Velocity to Pore Pressure  
14.4 Seismic Velocity Analysis for Pore Pressure Prediction: What We Have Learned and the Road Ahead  
14.5 Pore Pressure Prediction in Real-Time  
14.6 Integration of Disciplines  
14.7 Data Analytics and Machine Learning  
14.8 Summary  

Appendices  
A Empirical Relations for Fluid (Brine, Oil, Gas) Properties  
B Basic Definitions  
C Dimensionless Coordinate Transformation of 1D Basin Modeling Equation  

References  
Index  

*Color plates can be found between pages 268 and 269.*