

- Preface p. ix
- 1 The principles and limitations of geophysical exploration methods p. 1
- 1.1 Introduction p. 1
- 1.2 The survey methods p. 1
- 1.3 The problem of ambiguity in geophysical interpretation p. 6
- 1.4 The structure of the book p. 7
- 2 Geophysical data processing p. 8
- 2.1 Introduction p. 8
- 2.2 Digitization of geophysical data p. 8
- 2.3 Spectral analysis p. 10
- 2.4 Waveform processing p. 13
  - 2.4.1 Convolution p. 13
  - 2.4.2 Deconvolution p. 16
  - 2.4.3 Correlation p. 16
- 2.5 Digital filtering p. 17
  - 2.5.1 Frequency filters p. 18
  - 2.5.2 Inverse (deconvolution) filters p. 19
- 2.6 Imaging and modelling p. 19
  - Problems p. 20
  - Further reading p. 20
- 3 Elements of seismic surveying p. 21
  - 3.1 Introduction p. 21
  - 3.2 Stress and strain p. 21
  - 3.3 Seismic waves p. 22
    - 3.3.1 Body waves p. 23
    - 3.3.2 Surface waves p. 24
    - 3.3.3 Waves and rays p. 25
  - 3.4 Seismic wave velocities of rocks p. 26
  - 3.5 Attenuation of seismic energy along ray paths p. 27
  - 3.6 Ray paths in layered media p. 28
    - 3.6.1 Reflection and transmission of normally incident seismic rays p. 28
    - 3.6.2 Reflection and refraction of obliquely incident rays p. 30
    - 3.6.3 Critical refraction p. 31
    - 3.6.4 Diffraction p. 31
  - 3.7 Reflection and refraction surveying p. 32
  - 3.8 Seismic data acquisition systems p. 33
    - 3.8.1 Seismic sources and the seismic/acoustic spectrum p. 34
    - 3.8.2 Seismic transducers p. 39
    - 3.8.3 Seismic recording systems p. 41
    - Problems p. 42
    - Further reading p. 42
- 4 Seismic reflection surveying p. 43
  - 4.1 Introduction p. 43
  - 4.2 Geometry of reflected ray paths p. 43
    - 4.2.1 Single horizontal reflector p. 43
    - 4.2.2 Sequence of horizontal reflectors p. 45

- 4.2.3 Dipping reflector p. 46
- 4.2.4 Ray paths of multiple reflections p. 47
- 4.3 The reflection seismogram p. 48
  - 4.3.1 The seismic trace p. 48
  - 4.3.2 The shot gather p. 49
  - 4.3.3 The CMP gather p. 50
- 4.4 Multichannel reflection survey design p. 51
- 4.4.1 Vertical and horizontal resolution p. 52
- 4.4.2 Design of detector arrays p. 53
- 4.4.3 Common mid-point (CMP) surveying p. 54
- 4.4.4 Display of seismic reflection data p. 57
- 4.5 Time corrections applied to seismic traces p. 57
- 4.6 Static correction p. 57
- 4.7 Velocity analysis p. 59
- 4.8 Filtering of seismic data p. 61
  - 4.8.1 Frequency filtering p. 62
  - 4.8.2 Inverse filtering (deconvolution) p. 62
  - 4.8.3 Velocity filtering p. 65
- 4.9 Migration of reflection data p. 67
- 4.10 3D seismic reflection surveys p. 72
- 4.11 Three component (3C) seismic reflection surveys p. 76
- 4.12 4D seismic reflection surveys p. 77
- 4.13 Vertical seismic profiling p. 79
- 4.14 Interpretation of seismic reflection data p. 80
  - 4.14.1 Structural analysis p. 81
  - 4.14.2 Stratigraphical analysis (seismic stratigraphy) p. 82
  - 4.14.3 Seismic modelling p. 84
  - 4.14.4 Seismic attribute analysis p. 85
- 4.15 Single-channel marine reflection profiling p. 86
  - 4.15.1 Shallow marine seismic sources p. 89
  - 4.15.2 Sidescan sonar systems p. 90
- 4.16 Applications of seismic reflection surveying p. 92
  - Problems p. 97
  - Further reading p. 98
- 5 Seismic refraction surveying p. 99
- 5.1 Introduction p. 99
- 5.2 Geometry of refracted ray paths: planar interfaces p. 99
  - 5.2.1 Two-layer case with horizontal interface p. 100
  - 5.2.2 Three-layer case with horizontal interface p. 101
  - 5.2.3 Multilayer case with horizontal interfaces p. 102
  - 5.2.4 Dipping-layer case with planar interfaces p. 102
  - 5.2.5 Faulted planar interfaces p. 104
- 5.3 Profile geometries for studying planar layer problems p. 105
- 5.4 Geometry of refracted ray paths: irregular (non-planar) interfaces p. 106
  - 5.4.1 Delay time p. 106
  - 5.4.2 The plus-minus interpretation method p. 108

- 5.4.3 The generalized reciprocal method p. 109
- 5.5 Construction of wavefronts and ray-tracing p. 110
- 5.6 The hidden and blind layer problems p. 110
- 5.7 Refraction in layers of continuous velocity change p. 112
- 5.8 Methodology of refraction profiling p. 112
- 5.8.1 Field survey arrangements p. 112
- 5.8.2 Recording scheme p. 113
- 5.8.3 Weathering and elevation corrections p. 114
- 5.8.4 Display of refraction seismograms p. 115
- 5.9 Other methods of refraction surveying p. 115
- 5.10 Seismic tomography p. 117
- 5.11 Applications of seismic refraction surveying p. 119
- 5.11.1 Engineering and environmental surveys p. 119
- 5.11.2 Hydrological surveys p. 120
- 5.11.3 Crustal seismology p. 120
- 5.11.4 Two-ship seismic surveying: combined refraction and reflection surveying p. 122
  - Problems p. 123
  - Further reading p. 124
- 6 Gravity surveying p. 125
- 6.1 Introduction p. 125
- 6.2 Basic theory p. 125
- 6.3 Units of gravity p. 126
- 6.4 Measurement of gravity p. 126
- 6.5 Gravity anomalies p. 129
- 6.6 Gravity anomalies of simple-shaped bodies p. 130
- 6.7 Gravity surveying p. 132
- 6.8 Gravity reduction p. 133
  - 6.8.1 Drift correction p. 133
  - 6.8.2 Latitude correction p. 133
  - 6.8.3 Elevation corrections p. 134
  - 6.8.4 Tidal correction p. 136
  - 6.8.5 Eotvos correction p. 136
  - 6.8.6 Free-air and Bouguer anomalies p. 136
- 6.9 Rock densities p. 137
- 6.10 Interpretation of gravity anomalies p. 139
  - 6.10.1 The inverse problem p. 139
  - 6.10.2 Regional fields and residual anomalies p. 139
  - 6.10.3 Direct interpretation p. 140
  - 6.10.4 Indirect interpretation p. 142
- 6.11 Elementary potential theory and potential field manipulation p. 144
- 6.12 Applications of gravity surveying p. 147
  - Problems p. 150
  - Further reading p. 153
- 7 Magnetic surveying p. 155
  - 7.1 Introduction p. 155
  - 7.2 Basic concepts p. 155

- 7.3 Rock magnetism p. 158
- 7.4 The geomagnetic field p. 159
- 7.5 Magnetic anomalies p. 160
- 7.6 Magnetic surveying instruments p. 162
  - 7.6.1 Introduction p. 162
  - 7.6.2 Fluxgate magnetometer p. 162
  - 7.6.3 Proton magnetometer p. 163
  - 7.6.4 Optically pumped magnetometer p. 164
  - 7.6.5 Magnetic gradiometers p. 164
- 7.7 Ground magnetic surveys p. 164
- 7.8 Aeromagnetic and marine surveys p. 164
- 7.9 Reduction of magnetic observations p. 165
  - 7.9.1 Diurnal variation correction p. 165
  - 7.9.2 Geomagnetic correction p. 166
  - 7.9.3 Elevation and terrain corrections p. 166
- 7.10 Interpretation of magnetic anomalies p. 166
  - 7.10.1 Introduction p. 166
  - 7.10.2 Direct interpretation p. 168
  - 7.10.3 Indirect interpretation p. 170
  - 7.11 Potential field transformations p. 172
- 7.12 Applications of magnetic surveying p. 173
- Problems p. 180
  - Further reading p. 181
- 8 Electrical surveying p. 183
  - 8.1 Introduction p. 183
  - 8.2 Resistivity method p. 183
    - 8.2.1 Introduction p. 183
    - 8.2.2 Resistivities of rocks and minerals p. 183
    - 8.2.3 Current flow in the ground p. 184
    - 8.2.4 Electrode spreads p. 186
    - 8.2.5 Resistivity surveying equipment p. 186
    - 8.2.6 Interpretation of resistivity data p. 187
    - 8.2.7 Vertical electrical sounding interpretation p. 188
    - 8.2.8 Constant separation traversing interpretation p. 193
    - 8.2.9 Limitations of the resistivity method p. 196
    - 8.2.10 Applications of resistivity surveying p. 196
  - 8.3 Induced polarization (IP) method p. 199
    - 8.3.1 Principles p. 199
    - 8.3.2 Mechanisms of induced polarization p. 199
    - 8.3.3 Induced polarization measurements p. 200
    - 8.3.4 Field operations p. 201
    - 8.3.5 Interpretation of induced polarization data p. 201
    - 8.3.6 Applications of induced polarization surveying p. 202
  - 8.4 Self-potential (SP) method p. 203
    - 8.4.1 Introduction p. 203
    - 8.4.2 Mechanism of self-potential p. 203

- 8.4.3 Self-potential equipment and survey procedure p. 203
- 8.4.4 Interpretation of self-potential anomalies p. 204
- Problems p. 205
- Further reading p. 207
- 9 Electromagnetic surveying p. 208
- 9.1 Introduction p. 208
- 9.2 Depth of penetration of electromagnetic fields p. 208
- 9.3 Detection of electromagnetic fields p. 209
- 9.4 Tilt-angle methods p. 209
- 9.4.1 Tilt-angle methods employing local transmitters p. 210
- 9.4.2 The VLF method p. 210
- 9.4.3 The AFMAG method p. 212
- 9.5 Phase measuring systems p. 212
- 9.6 Time-domain electromagnetic surveying p. 214
- 9.7 Non-contacting conductivity measurement p. 216
- 9.8 Airborne electromagnetic surveying p. 218
- 9.8.1 Fixed separation systems p. 218
- 9.8.2 Quadrature systems p. 220
- 9.9 Interpretation of electromagnetic data p. 221
- 9.10 Limitations of the electromagnetic method p. 221
- 9.11 Telluric and magnetotelluric field methods p. 221
- 9.11.1 Introduction p. 221
- 9.11.2 Surveying with telluric currents p. 222
- 9.11.3 Magnetotelluric surveying p. 224
- 9.12 Ground-penetrating radar p. 225
- 9.13 Applications of electromagnetic surveying p. 227
- Problems p. 228
- Further reading p. 230
- 10 Radiometric surveying p. 231
- 10.1 Introduction p. 231
- 10.2 Radioactive decay p. 231
- 10.3 Radioactive minerals p. 232
- 10.4 Instruments for measuring radioactivity p. 233
- 10.4.1 Geiger counter p. 233
- 10.4.2 Scintillation counter p. 233
- 10.4.3 Gamma-ray spectrometer p. 233
- 10.4.4 Radon emanometer p. 234
- 10.5 Field surveys p. 235
- 10.6 Example of radiometric surveying p. 235
- Further reading p. 235
- 11 Geophysical borehole logging p. 236
- 11.1 Introduction to drilling p. 236
- 11.2 Principles of well logging p. 236
- 11.3 Formation evaluation p. 237
- 11.4 Resistivity logging p. 237
- 11.4.1 Normal log p. 238

- 11.4.2 Lateral log p. 239
- 11.4.3 Laterolog p. 240
- 11.4.4 Microlog p. 241
- 11.4.5 Porosity estimation p. 241
- 11.4.6 Water and hydrocarbon saturation estimation p. 241
- 11.4.7 Permeability estimation p. 242
- 11.4.8 Resistivity dipmeter log p. 242
- 11.5 Induction logging p. 243
- 11.6 Self-potential logging p. 243
- 11.7 Radiometric logging p. 244
  - 11.7.1 Natural gamma radiation log p. 244
  - 11.7.2 Gamma-ray density log p. 244
  - 11.7.3 Neutron-gamma-ray log p. 245
- 11.8 Sonic logging p. 246
- 11.9 Temperature logging p. 247
- 11.10 Magnetic logging p. 247
  - 11.10.1 Magnetic log p. 247
  - 11.10.2 Nuclear magnetic resonance log p. 247
- 11.11 Gravity logging p. 247
  - Problems p. 248
  - Further reading p. 249
- Appendix SI, c.g.s. and Imperial (customary USA) units and conversion factors p. 250
- References p. 251
- Index p. 257