

Contents

1	The Basis of Engineering Geology	1
	(with John Knill)	
1.1	Development of Engineering Geology	1
1.2	Aims of Engineering Geology	3
1.3	Attaining the Aims	4
1.4	Materials and Mass Fabric	5
1.5	Mass	7
1.6	Environmental Factors	8
	1.6.1 Climate	8
	1.6.2 Stress	9
	1.6.3 Natural Hazards	10
	1.6.4 Dynamic Processes	13
	1.6.5 Time	14
1.7	Analysis	15
1.8	Essential Definitions	15
1.9	Training and Professional Development in Engineering Geology	16
1.10	Further Reading	18
	Part I - Investigating the Ground	19
2	Geological Materials	21
	(with Michael de Freitas)	
2.1	Important Characteristics of Geological Materials	21
	2.1.1 Sediments	21
	2.1.2 Intact Rock Materials	22
	2.1.3 Fluids and Gasses	23
2.2	Description of Materials	23
2.3	Properties and their Measurement	26
	2.3.1 Types of Test	28
	2.3.2 Limitations of Testing	29
	2.3.3 Size and Shape of Sample	29
	2.3.4 Rate of Loading, Testing Machine and Platens	30
	2.3.5 Standards	30
2.4	Density and Unit Weight	31
2.5	Porosity and Permeability	33

2.5.1	Porosity	33
2.5.2	Permeability	34
2.6	Strength	36
2.6.1	Water Content and Drainage	36
2.6.2	Strength Tests	37
2.7	Deformation	42
2.7.1	Types of Rock Deformation	43
2.7.2	Consolidation of Soils	43
2.8	Abrasiveness	45
2.9	Environmental Reactivity	46
2.10	Index Tests	46
2.10.1	Soils	46
2.10.2	Rocks	47
2.11	Range of Values for Material Properties	49
2.11.1	Soils	50
2.11.2	Rocks	55
2.12	Further Reading	61
3	Geological Masses	63
	(with Robert Hack)	
3.1	Mass Fabric	63
3.1.1	Discontinuities	63
3.1.2	Shear Strength	64
3.1.3	Persistence (Continuity)	70
3.1.4	Orientation	72
3.1.5	Spacing	74
3.2	Weathering	76
3.2.1	Influence of Weathering on Rock Mass Properties	76
3.2.2	Susceptibility to Weathering	78
3.2.3	Standard Weathering Description Systems	78
3.2.4	Weathering Description and Zonation	80
3.3	Ground Mass Description	83
3.3.1	General Mass Description	83
3.3.2	Core Logging	84
3.3.3	A Theoretical Example	87
3.4	Further Reading	90
4	Maps	91
	(with Robert Hack)	
4.1	Maps	91
4.1.1	Published Geological Maps	91
4.1.2	Published Engineering Geological Maps	92
4.2	Geological Map Making	92
4.2.1	Linking the Data	93
4.3	Understanding Geological Maps	94
4.3.1	Interpretation of Geological Maps – Example	99
4.4	Mapping at a Small Scale	101

4.4.1	Starting	102
4.4.2	Covering the Ground	102
4.4.3	Hazards	103
4.5	Mapping at a Large Scale	103
4.5.1	Foundation Areas and Excavations	104
4.5.2	Rock Slopes and Major Outcrops	104
4.5.3	Tunnels	108
4.5.4	Mines	110
4.5.5	Natural Cavities	111
4.6	Engineering Geological Maps	111
4.6.1	The Past	111
4.6.2	The Present	113
4.6.3	Symbology	114
4.6.4	Current Developments	114
4.7	Quality of Published Information and Limitation of Liability	118
4.8	An Aid to Engineering Geological Mapping	118
4.8.1	Factors in the PRI	119
4.8.2	Calculating the Problem Recognition Index	122
4.9	Rock Mass Classification	123
4.9.1	Classification Systems	123
4.9.2	Discussion	130
4.10	Further Reading	131
5	Recovery of Samples	133
	(with Ian Higginbottom)	
5.1	Purpose and Principles	133
5.1.1	Drilling and Sampling	134
5.2	Drilling and Sampling in Rock	135
5.2.1	Rotary Core Drilling	135
5.2.2	Drills	137
5.3	Drilling Tools	139
5.3.1	Core Bits	139
5.3.2	Core Barrels	140
5.3.3	Flushing Media	140
5.3.4	Core and Core Barrel Sizes	141
5.3.5	Extraction and Storage of Cores	142
5.4	Drilling Process	142
5.4.1	Core Recovery	142
5.4.2	Efficiency in Drilling	143
5.4.3	Integral Core Sampling	144
5.4.4	Oriented Cores	144
5.5	Drilling and Sampling in Soil	145
5.5.1	Percussion ("Shell and Auger") Boring and Driven Tube Samples ..	147
5.5.2	Continuous Soil Sampling	149
5.5.3	Power Augers	150
5.5.4	Hand Augers	150
5.5.5	Special Samplers	150

5.6	Daily Drilling Records	151
5.7	Probe Drilling	151
5.7.1	Trial Excavations	153
5.8	Boring and Sampling over Water	154
5.8.1	Pushed and Driven Wire Line Samplers	154
5.8.2	Submerged Rotary Rigs	155
5.8.3	Vibro-Corers	155
5.8.4	Electro-Corers	155
5.8.5	Submerged Remote Control Rotary Corers	156
5.8.6	Gravity Samplers and Stationary Piston Corers	156
5.8.7	Sample Quantity and Quality	156
5.9	Contaminated Land	157
5.10	Further Reading	158
6	Field Tests and Measurements	159
	(with Ian Higginbottom)	
6.1	Introduction	159
6.2	Tests in Boreholes	159
6.2.1	Resistance to Penetration	160
6.2.2	Strength and Deformation Tests	165
6.2.3	Permeability Tests	167
6.2.4	Measurements of In Situ Stress	171
6.3	Tests in Large Diameter Boreholes, Shafts and Tunnels	172
6.3.1	Plate Bearing Test	173
6.3.2	In Situ Shear Tests	176
6.3.3	Other Tests	177
6.4	Measurements in Boreholes and Excavations	177
6.4.1	Standpipes and Piezometers	178
6.4.2	Extensometers	180
6.4.3	Inclinometers	181
6.4.4	Settlement Gauges	182
6.4.5	Pressure Cells	182
6.5	Engineering Geophysics	182
6.5.1	Geophysical Surveys	184
6.5.2	Choice of Methods	186
6.5.3	Contaminated Land	186
6.6	Seismic Methods	187
6.6.1	Reflection Seismic Techniques	190
6.6.2	Continuous Seismic Profiling	191
6.6.3	Seismic Refraction Methods	193
6.6.4	Down-Hole and Cross-Hole Shooting	195
6.6.5	Particular Applications of the Seismic Method	195
6.7	Electrical Resistivity Methods	200
6.8	Magnetic Methods	202
6.8.1	Electromagnetic Techniques	204
6.9	Gravity Methods	206
6.10	Further Reading	207

7	Organisation, Design and Reporting of Site Investigations	209
	(with John Knill)	
7.1	Stages of Investigation	209
7.1.1	Project Conception Stage	209
7.1.2	Preliminary Investigation Stage	210
7.1.3	Main Investigation Stage	210
7.1.4	Construction Investigation Stage	211
7.1.5	Post-Construction Investigation Stage	211
7.2	Design of Site Investigations	212
7.2.1	Building the Geotechnical Model	213
7.2.2	Guidelines for Design of an SI	214
7.3	Progressive Evaluation of Site Investigation Data	215
7.4	Investigation Progress and Engineering Design	216
7.5	Tender Visits	217
7.6	Supervision of Investigating Works	217
7.7	The Engineering Geological Situation	218
7.8	Investigation Reports	219
7.9	The Form of the Report	219
7.9.1	Other Aspects of Report Preparation	221
7.9.2	Borehole Records	222
7.10	Further Reading	225
	Part II • Ground Behaviour	227
8	Ground Response to Engineering and Natural Processes	229
	(with John Knill)	
8.1	Engineering Processes	229
8.2	Natural Processes	232
8.3	Recognising Problems	232
8.4	Groundwater	235
8.4.1	Common Problems With Groundwater in Engineering	236
8.4.2	Theory of Groundwater Lowering	238
8.4.3	Excluding Water	240
8.4.4	Inflow into Tunnels	241
8.4.5	Water Outflow	244
8.4.6	Links to Rock Mass Classification	244
8.5	Conclusion	245
8.6	Further Reading	245
9	Withdrawal of Support by Surface Excavations	247
	(with Michael de Freitas)	
9.1	Slope Movements	247
9.2	Simple Slope Failure	248
9.3	The Stability of Slopes in Soil	251
9.3.1	Dry Slopes in Granular Soils	251
9.3.2	Seepage Parallel to Slope	251
9.3.3	Rotational Failure	252

9.3.4	The Stability of Tips and Spoil Heaps	255
9.4	Slopes in Rock	256
9.4.1	The Strength of Discontinuities	256
9.4.2	Modes of Failure	257
9.4.3	2D Theory versus 3D Reality	261
9.5	Engineering Excavations	262
9.5.1	Surface Excavations in Rock	262
9.5.2	Excavation Underwater	266
9.6	Investigations of Slope Stability	268
9.6.1	Investigations for the Design of Excavated Slopes	268
9.6.2	Investigations of Existing Slopes	270
9.7	Design of Slopes	273
9.7.1	Benching on Slopes	274
9.7.2	Drainage	275
9.7.3	The Effect of Excavation Technique on Slope Stability	275
9.8	Existing Landslides	277
9.8.1	Recognition and Identification	277
9.8.2	Rates of Movement	279
9.8.3	Extent of Landslides	282
9.9	Remedial Works for Slope Instability	283
9.9.1	Methods of Stabilisation	284
9.9.2	Remedial Works for Rock Falls	290
9.10	Further Reading	294
10	Withdrawal of Support by Underground Excavations	295
	(with Robert Hack)	
10.1	Introduction	295
10.2	Stress	295
10.2.1	In Situ Stress Field	295
10.2.2	Man Induced Stresses	298
10.2.3	Stress Measurements	298
10.3	Stress around an Underground Excavation	298
10.3.1	A Circular Opening in a Linear Elastic, Homogeneous and Isotropic Medium	300
10.3.2	A Circular Opening in an Elasto-Plastic or Brittle, Homogeneous and Isotropic Medium	301
10.4	Stress Related Issues	302
10.4.1	Excavations in a Discontinuous Medium	302
10.4.2	Swelling Materials	303
10.4.3	Dynamic Stresses – Earthquakes	304
10.4.4	Failure Modes and Need for Support	304
10.4.5	Stresses around Portals	305
10.4.6	Stand-Up Time and Time Effects	306
10.5	Excavation Issues	307
10.5.1	Water and Underground Excavations	307
10.5.2	Excavation	308

10.6	Machine Methods of Excavation	310
10.6.1	Tunnel Boring Machines	311
10.7	Blasting	314
10.7.1	Smooth Wall Blasting and Pre-Splitting	314
10.7.2	Conventional Large-Hole Blasting	315
10.7.3	Advantages and Disadvantages of Blasting	315
10.8	Ground Improvement and Support	316
10.8.1	Ground Improvement	316
10.8.2	Support	319
10.8.3	New Austrian Tunnelling Method (NATM)	323
10.9	Site Investigation for Underground Excavations	323
10.9.1	Initial Estimates	324
10.9.2	On-going Investigations	325
10.9.3	Site Investigation for Surface Effects of Tunnelling	327
10.10	Subsidence	327
10.10.1	Subsidence due to a Single Tunnel	327
10.10.2	Subsidence due to Mining	328
10.11	Present Mining	328
10.11.1	Mining Sub-Horizontal Deposits	328
10.11.2	Mining Sub-Vertical Deposits	332
10.12	Past Mining	333
10.12.1	Bell Pits	333
10.12.2	Room and Pillar Workings	334
10.13	Mine Stability	336
10.13.1	Pillar Failure	337
10.13.2	Mine Stability Analysis	339
10.13.3	After Effects of Mining	340
10.14	Site Investigations for Subsidence Areas	343
10.14.1	Detection of Old Mine Workings	343
10.14.2	Investigation Techniques	344
10.15	Further Reading	347
11	Static Loading of the Ground	349
	(with Michiel Maurenbrecher)	
11.1	Introduction	349
11.1.1	Types of Foundation	350
11.1.2	Distribution of Stress under a Foundation	352
11.2	Bearing Capacity in Soils	353
11.2.1	Ultimate Bearing Capacity	354
11.2.2	Safe Bearing Capacity and Allowable Pressures	356
11.2.3	Bearing Capacities on Boulder Bearing Soils	356
11.3	Settlement on Soils	357
11.3.1	Immediate (Short-Term) Settlement	357
11.3.2	Consolidation (Long-Term) Settlement	358
11.4	Bearing Capacity on Rock Masses	359
11.5	Foundation Settlement on Rock	362

11.6	Preliminary Estimates by the Engineering Geologist	364
11.6.1	Estimates of Bearing Capacity	364
11.6.2	Influence of Geological Factors on Foundation Performance	366
11.7	Foundations on Slopes	375
11.8	Construction Problems	377
11.8.1	Foundation Excavations	377
11.8.2	Stepped Foundations	378
11.8.3	Foundations Piled to Rock	378
11.9	Field Assessment of Exposed Foundations	382
11.10	Further Reading	386
12	Dynamic Loading of the Ground	387
	(with Michiel Maurenbrecher)	
12.1	Engineering Geology and Earthquakes	387
12.2	Sources and Characteristics of Earthquakes	388
12.2.1	Magnitude	389
12.2.2	Intensity	390
12.2.3	Amplification	391
12.3	Liquefaction	391
12.4	Other Effects of Earthquakes	396
12.5	Assessing Seismic Risk and Seismic Hazard	396
12.6	Ground Engineering Design against Earthquake Hazards	398
12.7	After the Earthquake	399
12.8	Further Reading	400
13	Ground Reaction to Changes of Fluid and Gas Pressures	401
	(with Michiel Maurenbrecher)	
13.1	Subsidence due to the Pumping Out of Fluid	401
13.1.1	The Principle of Effective Stress	402
13.1.2	The Role of the Engineering Geologist	404
13.2	Water	405
13.2.1	Subsidence in Unconfined Aquifers	406
13.2.2	Subsidence in Confined Aquifers	409
13.3	Subsidence in Rock Aquifers and Reservoirs	411
13.3.1	Extraction of Water	411
13.3.2	Extraction of Oil and Gas	412
13.3.3	Extraction of Gas	414
13.4	Reduction and Monitoring of Subsidence from Fluid Withdrawal	415
13.4.1	Measuring Consolidation and Compaction	416
13.5	Further Reading	418
	Epilogue	419
	References	421
	Index	429