

Preface.....	13
What the Book Describes	13
Denver's Geological Context	16
Organization of the Book	17
What the Book Does Not Describe	19
Names of Rock Units Used in This Book.....	20
Chapter 1 — Peaks, Hogbacks, and the Basin — Denver's Backdrop.....	22
The Front Range	24
The Colorado Piedmont and the High Plains.....	26
The Denver Basin.....	27
Lava Flows and Giant Floods.....	29
Glacial Cirques, River Terraces, Mesas, Landslides, and Stream Cuts — Recent Geology Around Denver.....	30
Chapter 2 — Mountain Building and Piles of Sediment — A Ten-Minute Geology Course	32
A Science of Change	32
Geologic Time.....	32
The Geologic Time Scale	34
Plate Tectonic Processes	36
Rock Cycles.....	38
Rock Types	40
Composition of Rocks, Minerals, and Crystallization	42
Basic Principles	44
Faults and Unconformities	46
The Stratigraphic Column around Denver	47
A Note on Named Stratigraphic Units	49
Depositional Patterns.....	51
Climatic, Geographic, and Sea-Level Changes	53
Mountain Ranges and Basins	53
Other Earth Movements	54
Landslides, Earthflows, and Slumps.....	54

Geomorphology and Recent Evolution of the Landscape	55
Channels, Distributary Fans, and Deltas	55
River and Stream Evolution	56
Formation of Terraces and Pediments.....	56
Stream Capture.....	56
Chapter 3 – High Peaks, Colorado Piedmont, and the Denver Basin – A Short Geological History of the Area.....	58
Precambrian Denver	59
The Great Unconformity.....	61
The Pennsylvanian	62
The Permian	63
The Triassic	64
The Jurassic	64
The Cretaceous.....	65
The Rise of the Modern Rocky Mountains	66
The Tertiary and Quaternary Periods.....	67
Variations along the Front Range and Mountain Front West of Denver	68
Denver's Red Rocks.....	69
Chapter 4 – Backbone of the Continent – the Precambrian Core	71
The Basic Precambrian History	72
Life in the Precambrian	72
Characteristics of the Core Rocks of the Front Range.....	73
What You Can See on the Field Trips	75
Archean Wyoming and the North American Craton.....	75
Chronology	77
Precambrian Tectonic History	79
Colorado Is Pieced Together – 1.80-1.70 Ga.....	79
Shearing and Injection of Granite Plutons – 1.44-1.36 Ga	80
How Do Geologists Know About These Rocks?	82
In the Lab	84
In the Field	85
Precambrian Rocks West of Denver	86
1.7 Billion-Year and Older Rocks	86

1.4 Billion-Year-Old Rocks	91
Chapter 5 — The Great Unconformity.....	96
The North American Framework for Late Proterozoic and Paleozoic Geology of the Area	97
What Geologists Know About Colorado During This Time	98
Middle to Late Proterozoic.....	98
Early Paleozoic	99
Cambrian Period	100
Ordovician	101
Silurian	101
Devonian.....	101
Mississippian.....	101
Boulder from the Later Proterozoic to the Pennsylvanian.....	102
Chapter 6 — Ancestral Rockies and Flatirons — Denver During the Pennsylvanian	103
Characteristics of the Fountain Formation	104
Variations in the Fountain along the Mountain Front.....	107
North America in the Pennsylvanian (318-299 Ma)	107
Colorado in the Pennsylvanian	108
The Ancestral Rockies.....	109
Axes of the Ancestral and Modern Front Ranges.....	111
The Pennsylvanian Context	112
The Pennsylvanian Big Picture	113
Final Notes on Denver in Pennsylvanian Time	114
Flatirons, Spires, and Outcrops along the Mountain Front	115
Chapter 7 — Dune Sands and Fetid Flats — Denver in the Permian and Triassic	116
The Permian Period	116
The Permian in Denver	117
The Fountain and Ingleside Formations	120
The Lyons Formation	120
The Lykins Formation	123
The Triassic in Denver	123
Chapter 8 — Jurassic Park.....	125

The Jurassic Context.....	125
The Ralston Creek Formation	126
The Morrison Formation.....	126
Chapter 9 – Cretaceous – Undersea Denver	128
An Overview of the Cretaceous in the Western Interior of North America	129
The Western Interior Seaway.....	130
Depositional Environments in the Late Cretaceous	132
Transgressive and Regressive Sequences	133
Mountain Building Events	133
The Cretaceous in the Denver Basin.....	134
The Dakota Hogback – Denver Becomes Beachfront Property	137
The Dakota Group West of Denver	140
The Lower Dakota Group – Lytle Formation and Plainview Sandstone.....	142
The Middle Dakota Group – Skull Creek Shale	144
The Upper Dakota Group – Muddy Sandstone and Other Sandstone Bodies	147
Floors of the Denver Sea -- Cretaceous Marine Deposits	147
The Benton Group (Benton Shale, Benton Formation).....	148
The Niobrara Formation	149
The Pierre Shale	151
Late Cretaceous Denver Beaches -- Fox Hills and Laramie Formations	155
The Fox Hills Formation	157
The Laramie Formation	160
Late Cretaceous Growth Faults.....	161
Chapter 10 – The Denver Basin.....	166
The Importance of Sedimentary Basins	166
Structure of the Denver Basin.....	167
Stratigraphy of the Denver Basin – Formations, Facies, and Confusion.....	169
Raynolds' Stratigraphic Approach.....	171
The Denver Basin Project	171
A View of the Basin	173
A Denver Basin Chronology.....	173
Description of the Rocks	173

Aquifers of the Denver Basin— and a Brief Discursion on Water Law	173
The Aquifers	173
The History	174
Chapter 11 — The Rise of the Rockies.....	177
The Rise of the Modern Front Range	177
Plate Tectonics and the Modern Front Range.....	178
Other Tectonic Models for the Laramide Orogeny.....	182
Tectonic ‘Style’ of the Front Range Uplift.....	182
The Exhumation of the Front Range and Block Faulting to the South.....	183
The Rocky Mountain Erosion Surface	184
Volcanism and Igneous Intrusions During the Late Cretaceous and Tertiary	187
Chapter 12 — Glaciers and Terraces — Quaternary Denver	188
Glaciation in the Front Range West of Denver.....	196
Dating Glacial Deposits	197
Pediments.....	199
River Terraces	199
Canyon Incision Rates and Weathering of Slopes.....	200
Paleovalleys in the Rocky Mountain Erosion Surface.....	201
Chapter 13 — Field Trips	203
Urban Geology Field Trips.....	204
Miscellaneous Notes on the Field Trips	204
Bearings	204
Field Trip A -- Mountain Front from Coal Creek to Chatfield Reservoir.....	205
Description	205
Location/Directions	205
Geological Maps	205
Transportation.....	205
Overview of the Geology.....	205
Road/Trail Log	207
Field Trip B — Golden Gate Canyon, White Ranch Park, and the Idaho Springs- Ralston Shear Zone	229
Description	229
Location/Directions	229

Geological Maps	229
Transportation.....	229
Overview of the Geology.....	229
Road/Trail Log	230
Waypoint	243
Field Trip C – Boulder Foothills	245
Acknowledgement	245
Description	245
Location/Directions	245
Geological Maps	245
Transportation.....	245
Overview of the Geology.....	245
Road/Trail Log	245
Field Trip D –Matthews/Winters Park and Red Rocks	246
Description	246
Location/Directions	246
Geological Maps	246
Transportation.....	246
Overview of the Geology.....	246
Road/Trail Log	246
Field Trip E – Dinosaur Ridge and Rooney Road	252
Description	252
Location/Directions	252
Geological Maps	252
Transportation.....	253
Overview of the Geology.....	253
History	253
Road/Trail Log	254
Field Trip F – Green Mountain.....	271
Description	271
Location/Directions	271
Geological Maps	271
Transportation.....	271

Overview of the Geology.....	271
Road/Trail Log	273
Field Trip G – Roxborough Park.....	279
Description	279
Location/Directions	279
Geological Maps	280
Transportation.....	280
Overview of the Geology.....	280
Road/Trail Log	282
Field Trip H – Castlewood Canyon.....	296
Description	296
Location/Directions	296
Geological Maps	296
Transportation.....	296
Overview of the Geology.....	296
Road/Trail Log	296
Field Trip I – Clear Creek Canyon	297
Description	297
Location/Directions	297
Geological Maps	297
Transportation.....	297
Overview of the Geology.....	297
Road/Trail Log	297
Field Trip J – West Chicago Creek to Hells Hole	298
Description	298
Location/Directions	298
Geological Maps	298
Transportation.....	298
Overview of the Geology.....	298
Road/Trail Log	298
Field Trip K – Golden and Colorado School of Mines.....	304
Description	304
Location/Directions	304

Geological Maps	304
Transportation.....	304
Overview of the Geology.....	304
Road/Trail Log	304
Field Trip L – Boulder Creek Batholith and Green Mountain Kimberlite.....	306
Acknowledgement	306
Description	306
Location/Directions	306
Geological Maps	307
Transportation.....	307
Overview of the Geology.....	307
Road/Trail Log	308
Field Trip M – West Side of the Front Range—Southern Segment	314
Description	314
Location/Directions	314
Geological Maps	315
Transportation.....	315
Overview of the Geology.....	315
Road/Trail Log	319
Field Trip N – Daniels Park–Jarre Creek–Wildcat Mountain–Perry Park...	335
Description	335
Location/Directions	336
Geological Maps	336
Transportation.....	336
Overview of the Geology.....	336
Road/Trail Log	336
Field Trip O – Waterton Canyon	347
Description	347
Location/Directions	347
Geological Maps	347
Transportation.....	347
Overview of the Geology.....	348
Road/Trail Log	348

Field Trip P – Garden of the Gods	355
Description	355
Location/Directions	355
Geological Maps	355
Transportation.....	355
Overview of the Geology.....	355
Road/Trail Log	355
Field Trip Q – Castle Rock.....	357
Description	357
Location/Directions	357
Geological Maps	357
Transportation.....	357
Overview of the Geology.....	357
Road/Trail Log	357
Field Trip R – I-70 Road Cut	359
Description	359
Location/Directions	359
Geological Maps	359
Transportation.....	359
Overview of the Geology.....	359
Road/Trail Log	359
Field Trip U – Mt. Falcon Park	360
Description	360
Location/Directions	360
Geological Maps	361
Transportation.....	361
Overview of the Geology.....	361
Road/Trail Log	361
Field Trip V – Bergen Park, Squaw Pass, Echo Lake, and Chicago Lakes	367
Description	367
Location/Directions	367
Geological Maps	367
Transportation.....	367

Overview of the Geology.....	367
Road/Trail Log	368
Field Trip W – Shadow Canyon Geomorphology	374
Acknowledgement	374
Description	374
Location/Directions	374
Geological Maps	374
Transportation.....	374
Overview of the Geology.....	374
Road/Trail Log	374
Field Trip Y – Manitou Springs	375
Description	375
Location/Directions	375
Geological Maps	375
Transportation.....	375
Overview of the Geology.....	375
Road/Trail Log	375
Field Trip Z – West Side of the Front Range—Northern Segment	376
Description	376
Location/Directions	376
Geological Maps	376
Transportation.....	376
Overview of the Geology.....	376
Road/Trail Log	377
Appendices.....	393
A: Further Reading and Resources.....	393
General Geology Texts and Literature	393
Web Resources	393
B: Basic Geology.....	394
Geologic Time Periods.....	394
The Geologic Time Scale	395
Index Fossils.....	403
Radiometric Dating and Its Relation to Other Dating Methods	404

Paleomagnetic Dating	410
Classification and Evolution of Rocks.....	411
Volcanoes.....	419
Folds, Faults, and Unconformities.....	420
Plate Tectonics.....	424
C: Using Topographic Maps.....	439
USGS 7½-Minute Series	440
Learning to Read Topographic Maps.....	441
D: Using Geological Maps.....	442
Rock Units	442
Abbreviations for Rock Units	442
Stratigraphic Cross-Sections	444
Other Symbols and Features	444
Reading Geological Maps.....	444
E: Topographic & Geological Maps of the Denver Area	446
F: GPS Positions of Field Sites.....	448
A Few GPS Nuances	448
Receiver Settings	449
Table Format	449
Glossary.....	450
Literature Cited.....	461
Index	493