

BRIEF CONTENTS

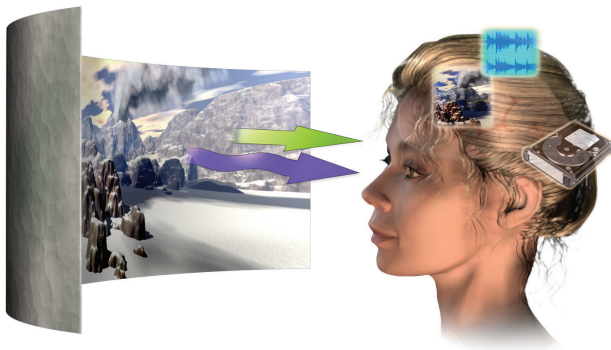
CHAPTER 1:	THE NATURE OF GEOLOGY	2
CHAPTER 2:	INVESTIGATING GEOLOGIC QUESTIONS	24
CHAPTER 3:	PLATE TECTONICS.....	48
CHAPTER 4:	EARTH MATERIALS	74
CHAPTER 5:	IGNEOUS ENVIRONMENTS	106
CHAPTER 6:	VOLCANOES AND VOLCANIC HAZARDS.....	138
CHAPTER 7:	SEDIMENTARY ENVIRONMENTS AND ROCKS.....	170
CHAPTER 8:	DEFORMATION AND METAMORPHISM.....	204
CHAPTER 9:	GEOLOGIC TIME.....	236
CHAPTER 10:	THE SEAFLOOR AND CONTINENTAL MARGINS ...	268
CHAPTER 11:	MOUNTAINS, BASINS, AND CONTINENTS	296
CHAPTER 12:	EARTHQUAKES AND EARTH'S INTERIOR.....	326
CHAPTER 13:	CLIMATE, WEATHER, AND THEIR INFLUENCES ON GEOLOGY	364
CHAPTER 14:	GLACIERS, SHORELINES, AND CHANGING SEA LEVELS	396
CHAPTER 15:	WEATHERING, SOIL, AND UNSTABLE SLOPES.....	436
CHAPTER 16:	STREAMS AND FLOODING.....	466
CHAPTER 17:	WATER RESOURCES	500
CHAPTER 18:	ENERGY AND MINERAL RESOURCES	526
CHAPTER 19:	GEOLOGY OF THE SOLAR SYSTEM	558

CONTENTS

Preface	xiv
Supplements	xxv
Acknowledgments	xxviii
About the Authors	xxxi

CHAPTER 1: THE NATURE OF GEOLOGY 2

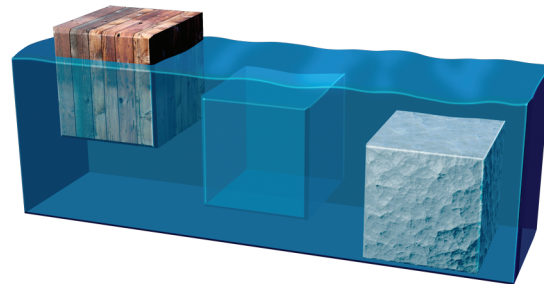
1.1 How Does Geology Influence Where and How We Live?	4
1.2 How Does Geology Help Explain Our World?	6
1.3 What Is Inside Earth?	8
1.4 What Processes Affect Our Planet?	10
1.5 How Do Rocks Form?	12
1.6 What Can Happen to a Rock?	14
1.7 How Do the Atmosphere, Water, and Life Interact with Earth's Surface?	16
1.8 What Is Earth's Place in the Solar System?	18
1.9 CONNECTIONS: How Is Geology Expressed in the Black Hills and in Rapid City?	20
1.10 INVESTIGATION: How Is Geology Affecting This Place?	22



CHAPTER 2: INVESTIGATING GEOLOGIC QUESTIONS 24

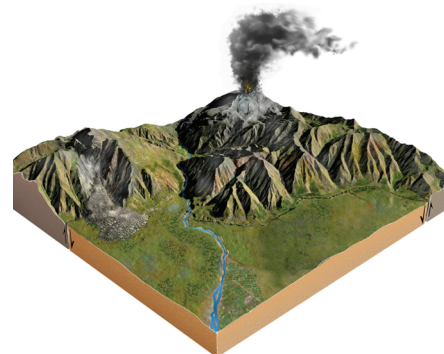
2.1 What Can We Observe in Landscapes?	26
2.2 How Do We Interpret Geologic Clues?	28
2.3 How Do We Depict Earth's Surface?	30
2.4 How Do We Depict Earth's Heights, Slopes, and Subsurface Geology?	32
2.5 How Are Geologic Problems Quantified?	34

2.6 How Do Geologists Refer to Rates and Time?	36
2.7 How Do We Investigate Geologic Questions?	38
2.8 How Do Scientific Ideas Get Established?	40
2.9 What Does a Geologist Do?	42
2.10 CONNECTIONS: How Did This Crater Form?	44
2.11 INVESTIGATION: What Is the Geologic History of Upheaval Dome?	46



CHAPTER 3: PLATE TECTONICS 48

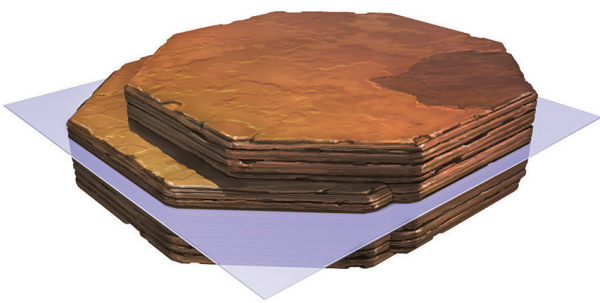
3.1 What Are the Major Features of Earth?	50
3.2 Why Do Some Continents Have Matching Shapes?	52
3.3 Where Do Earthquakes and Volcanoes Occur?	54
3.4 What Causes Tectonic Activity to Occur in Belts?	56
3.5 What Happens at Divergent Boundaries?	58
3.6 What Happens at Convergent Boundaries?	60
3.7 What Happens Along Transform Boundaries?	62
3.8 How Do Plates Move and Interact?	64
3.9 How Is Paleomagnetism Used to Determine Rates of Seafloor Spreading?	66
3.10 What Geologic Features Does Plate Tectonics Help Explain?	68
3.11 CONNECTIONS: Why Is South America Lopsided?	70
3.12 INVESTIGATION: Where Is the Safest Place to Live?	72



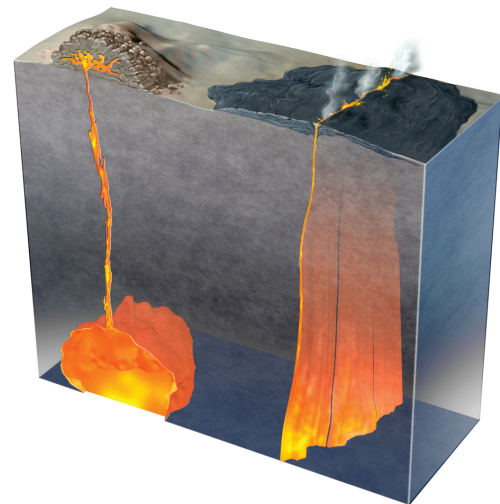
CHAPTER 4: EARTH MATERIALS

74

- 4.1 What Is the Difference Between a Rock and a Mineral? 76
- 4.2 How Are Minerals Put Together in Rocks? 78
- 4.3 How Do We Distinguish One Mineral from Another? 80
- 4.4 What Controls a Crystal's Shape? 82
- 4.5 What Causes Cleavage in Minerals? 84
- 4.6 How Are Minerals Classified? 86
- 4.7 What Is the Crystalline Structure of Silicate Minerals? 88
- 4.8 What Are Some Common Silicate Minerals? 90
- 4.9 What Are Some Common Nonsilicate Minerals? 92
- 4.10 Where Are Different Minerals Abundant? 94
- 4.11 What Are the Building Blocks of Minerals? 96
- 4.12 How Do Atoms Bond Together? 98
- 4.13 How Do Chemical Reactions Help Minerals Grow or Dissolve? 100
- 4.14 **CONNECTIONS:** How Are Minerals Used in Society? 102
- 4.15 **INVESTIGATION:** What Minerals Would You Use to Build a House? 104



- 5.5 How Do Rocks Melt? 116
- 5.6 How Do Igneous Rocks Form? 118
- 5.7 How Does Magma Move? 120
- 5.8 How Does Magma Solidify? 122
- 5.9 How Does Magma Form Along Divergent Plate Boundaries? 124
- 5.10 How Does Magma Form Along Convergent Plate Boundaries? 126
- 5.11 How Is Magma Generated at Hot Spots and Other Sites Away from Plate Boundaries? 128
- 5.12 How Do Large Magma Chambers Form and How Are They Expressed in Landscapes? 130
- 5.13 How Are Small Intrusions Formed and Expressed in Landscapes? 132
- 5.14 **CONNECTIONS:** How Did the Sierra Nevada Form? 134
- 5.15 **INVESTIGATION:** What Types of Igneous Processes Are Occurring Here? 136



CHAPTER 5: IGNEOUS ENVIRONMENTS

106

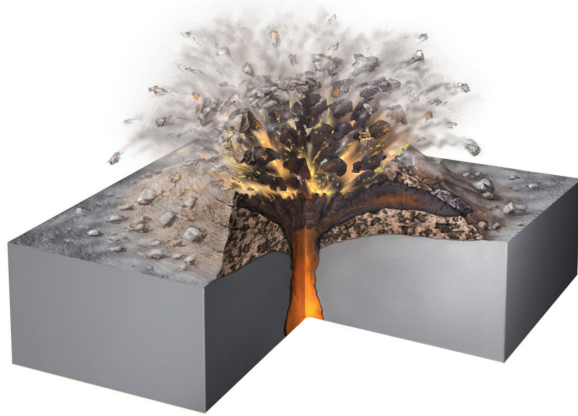
- 5.1 What Textures Do Igneous Rocks Display? 108
- 5.2 How Are Igneous Rocks Classified? 110
- 5.3 What Are Some Other Igneous Rocks? 112
- 5.4 How Do Temperature and Pressure Vary Inside Earth? 114

CHAPTER 6: VOLCANOES AND VOLCANIC HAZARDS

138

- 6.1 What Is and Is Not a Volcano? 140
- 6.2 What Controls the Style of Eruption? 142
- 6.3 What Features Characterize Basaltic Volcanoes? 144
- 6.4 How Do Shield Volcanoes Form? 146

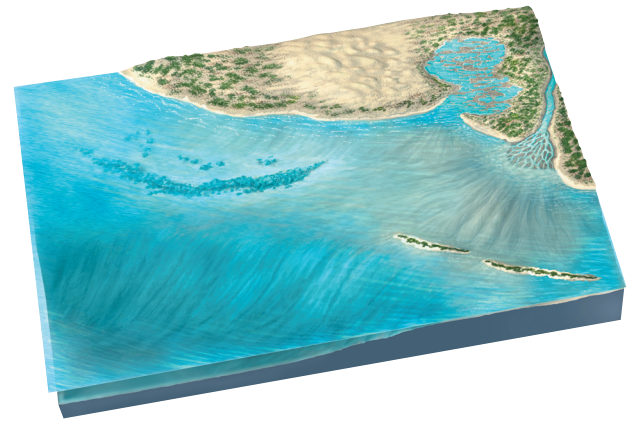
6.5 What Causes Flood Basalts?	148
6.6 What Are the Hazards of Basaltic Eruptions?	150
6.7 What Are Composite Volcanoes?	152
6.8 What Disasters Were Caused by Composite Volcanoes?	154
6.9 How Do Volcanic Domes Form?	156
6.10 Why Does a Caldera Form?	158
6.11 What Disasters Were Related to Calderas?	160
6.12 What Areas Have the Highest Potential for Volcanic Hazards?	162
6.13 How Do We Monitor Volcanoes?	164
6.14 CONNECTIONS: What Volcanic Hazards Are Posed by Mount Rainier?	166
6.15 INVESTIGATION: How Would You Assess Hazards on This Volcano?	168



CHAPTER 7: SEDIMENTARY ENVIRONMENTS AND ROCKS 170

7.1 What Sedimentary Environments Occur on Land?	172
7.2 What Sedimentary Environments Are Near Shorelines and in Oceans?	174
7.3 Where Do Clasts Come From?	176
7.4 What Are the Characteristics of Clastic Sediments?	178
7.5 What Types of Rocks Do Clastic Sediments Form?	180
7.6 What Are Nonclastic Sedimentary Rocks and How Do They Form?	182
7.7 Why Do Sedimentary Rocks Have Layers?	184
7.8 Where Do Breccia and Conglomerate Form?	186

7.9 Where Does Sandstone Form?	188
7.10 How Do Fine-Grained Clastic Rocks Form?	190
7.11 How Do Carbonate Rocks Form?	192
7.12 How Do Changing Environments Create a Sequence of Different Kinds of Sediments?	194
7.13 How Do We Study Sedimentary Sequences?	196
7.14 Why Are Sediments and Sedimentary Rocks Important to Our Society?	198
7.15 CONNECTIONS: How Did Sedimentary Layers West of Denver Form?	200
7.16 INVESTIGATION: What Is the Sedimentary History of This Plateau?	202



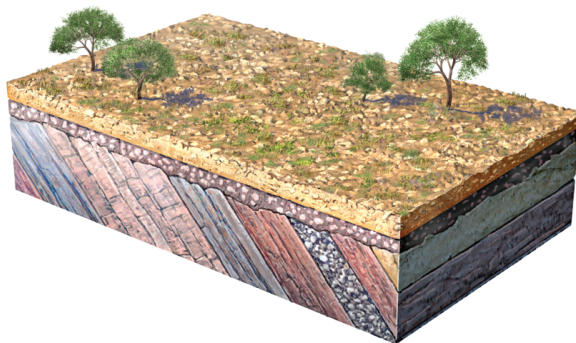
CHAPTER 8: DEFORMATION AND METAMORPHISM 204

8.1 How Do Rocks Respond to Stress?	206
8.2 How Do Rocks Respond to Changes in Stress, Temperature, and Fluids?	208
8.3 How Do Rocks Fracture?	210
8.4 What Are Different Types of Faults?	212
8.5 What Are Folds and How Are They Shaped?	214
8.6 What Are Some Metamorphic Features?	216
8.7 What Are Some Common Metamorphic Rocks?	218
8.8 How Does Metamorphism Occur?	220
8.9 Where Does Metamorphism Occur?	222
8.10 What Processes Occur in Extensional and Strike-Slip Settings?	224
8.11 How Are Different Structures and Metamorphic Features Related?	226

- 8.12** How Are Geologic Structures and Metamorphic Rocks Expressed in the Landscape? 228
- 8.13** How Do We Study Geologic Structures and Metamorphic Features? 230
- 8.14 CONNECTIONS:** What Is the Structural and Metamorphic History of New England? 232
- 8.15 INVESTIGATION:** What Structural and Metamorphic Events Occurred Here? 234

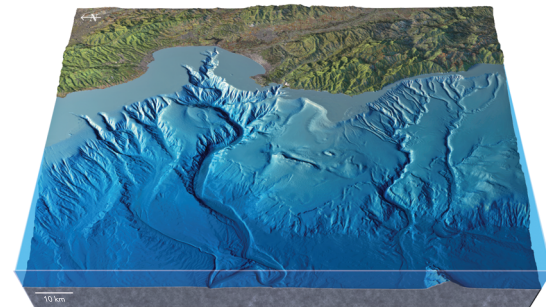
CHAPTER 9: GEOLOGIC TIME 236

- 9.1** How Do We Infer the Relative Ages of Events? 238
- 9.2** How Do We Study Ages of Landscapes? 240
- 9.3** What Is the Significance of an Unconformity? 242
- 9.4** How Are Ages Assigned to Rocks and Events? 244
- 9.5** What Are Fossils? 246
- 9.6** How and Why Did Living Things Change Through Geologic Time? 248
- 9.7** How Are Fossils Used to Infer Ages of Rocks? 250
- 9.8** How Was the Geologic Timescale Developed? 252
- 9.9** What Is the Evidence for the Age of Earth? 254
- 9.10** What Were Some Milestones in the Early History of Life on Earth? 256
- 9.11** What Were Some Milestones in the Later History of Life on Earth? 258
- 9.12** How Do We Reconstruct Geologic Histories? 260
- 9.13** Why Do We Investigate Geologic History? 262
- 9.14 CONNECTIONS:** What Is the History of the Grand Canyon? 264
- 9.15 INVESTIGATION:** What Is the Geologic History of This Place? 266



CHAPTER 10: THE SEAFLOOR AND CONTINENTAL MARGINS 268

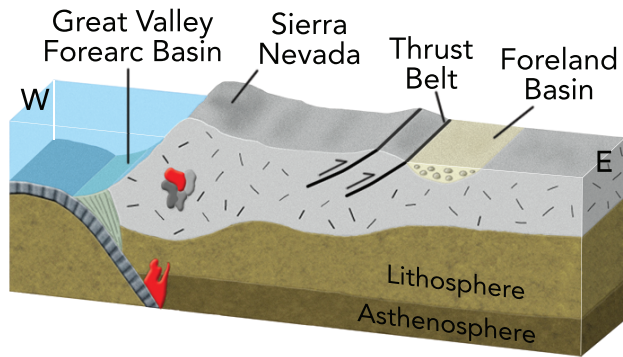
- 10.1** How Do We Explore the Seafloor? 270
- 10.2** What Processes Occur at Mid-Ocean Ridges? 272
- 10.3** What Are Major Features of the Deep Ocean? 274
- 10.4** How Do Oceanic Islands, Seamounts, and Oceanic Plateaus Form? 276
- 10.5** What Processes Form Island Arcs? 278
- 10.6** How Did Smaller Seas of the Pacific Form? 280
- 10.7** How Did Smaller Seas Near Eurasia Form? 282
- 10.8** How Do Reefs and Coral Atolls Form? 284
- 10.9** What Is the Geology of Continental Margins? 286
- 10.10** How Do Marine Salt Deposits Form? 288
- 10.11** How Did Earth's Modern Oceans Evolve? 290
- 10.12 CONNECTIONS:** How Did the Gulf of Mexico and the Caribbean Region Form? 292
- 10.13 INVESTIGATION:** How Did These Ocean Features and Continental Margins Form? 294



CHAPTER 11: MOUNTAINS, BASINS, AND CONTINENTS 296

- 11.1** Why Are Some Regions High in Elevation? 298
- 11.2** Where Do Mountain Belts and High Regions Form? 300
- 11.3** How Do Local Mountains Form? 302
- 11.4** Where Do Basins Form? 304
- 11.5** How Do Mountains and Basins Form at Convergent Continental Margins? 306
- 11.6** How Does Continental Extension Occur? 308
- 11.7** What Are the Characteristics and History of Continental Hot Spots? 310

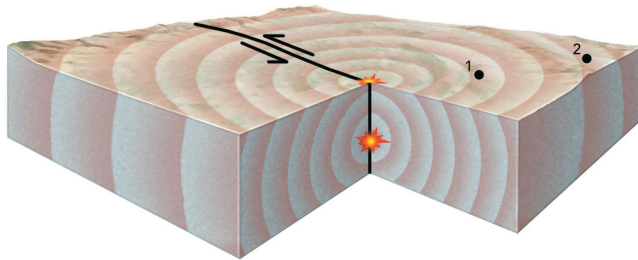
11.8 What Features Characterize the Interiors of Continents?	312
11.9 What Are Tectonic Terranes?	314
11.10 How Do Continents Form?	316
11.11 How Did the Continents Join and Split Apart?	318
11.12 CONNECTIONS 1: How Did the Appalachian and Ouachita Mountains Form?	320
11.13 CONNECTIONS 2: What Is the Geologic History of the Western United States?	322
11.14 INVESTIGATION: Where Will Mountains and Basins Form in This Region?	324



CHAPTER 12: EARTHQUAKES AND EARTH'S INTERIOR

326

12.1 What Is an Earthquake?	328
12.2 How Does Faulting Cause Earthquakes?	330



12.3 Where Do Most Earthquakes Occur?	332
12.4 What Causes Earthquakes Along Plate Boundaries and Within Plates?	334
12.5 How Do Earthquake Waves Travel?	336
12.6 How Do We Determine the Location and Size of an Earthquake?	338

12.7 How Do Earthquakes Cause Damage?	340
12.8 What Were Some Major North American Earthquakes?	342
12.9 What Were Some Recent Large Earthquakes?	344
12.10 How Does a Tsunami Form and Cause Destruction?	346
12.11 How Do We Study Earthquakes in the Field?	348
12.12 Can Earthquakes Be Predicted?	350
12.13 What Is the Potential for Earthquakes Along the San Andreas Fault?	352
12.14 How Do We Explore Earth's Subsurface?	354
12.15 What Do Seismic Waves Indicate About Earth's Interior?	356
12.16 How Do We Investigate Deep Processes?	358
12.17 CONNECTIONS: What Happened During the Great Alaskan Earthquake of 1964?	360
12.18 INVESTIGATION: Where Did This Earthquake Occur, and What Damage Might Be Expected?	362

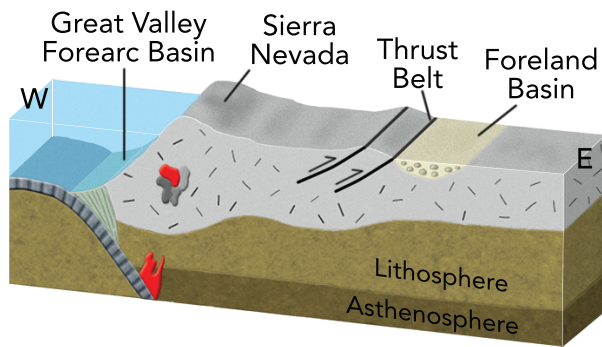
CHAPTER 13: CLIMATE, WEATHER, AND THEIR INFLUENCES ON GEOLOGY 364

13.1 What Causes Winds?	366
13.2 Why Does It Rain and Snow?	368
13.3 How Do Hurricanes, Tornadoes, and Other Storms Develop?	370
13.4 How Do Ocean Currents Influence Climate?	372
13.5 What Causes Short-Term Climatic Variations?	374
13.6 What Controls the Location of Rain Forests?	376
13.7 What Are Deserts and How Do They Form?	378
13.8 How Does Wind Transport Material?	380
13.9 What Features Are Common in Deserts?	382
13.10 What Is the Evidence for Climate Change?	384
13.11 What Factors Influence Climate Change?	386
13.12 What Is the Relationship Among Climate, Tectonics, and Landscape Evolution?	388
13.13 How Does Geology Influence Ecology?	390
13.14 CONNECTIONS: What Occurred During the Hurricane Seasons of 2004 and 2005?	392
13.15 INVESTIGATION: What Kinds of Climate and Weather Would Occur in This Place?	394

**CHAPTER 14:
GLACIERS, SHORELINES,
AND CHANGING SEA LEVELS**

396

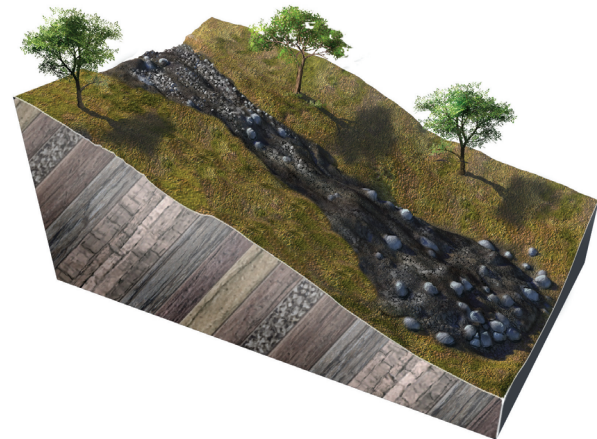
14.1 What Are Glaciers?	398
14.2 How Do Glaciers Form, Move, and Vanish?	400
14.3 What Happens When Glaciers Erode into the Landscape?	402
14.4 What Features Do Glacial Sediments Form?	404
14.5 What Features Are Peripheral to Glaciers?	406
14.6 What Is the Evidence for Past Glaciations?	408
14.7 What Happened During Past Ice Ages?	410
14.8 What Starts and Stops Glacial Episodes?	412
14.9 What Processes Occur Along Shorelines?	414
14.10 What Causes High Tides and Low Tides?	416
14.11 How Do Waves Form and Propagate?	418
14.12 How Is Material Eroded, Transported, and Deposited Along Shorelines?	420
14.13 What Landforms Occur Along Shorelines?	422
14.14 What Are Some Challenges of Living Along Shorelines?	424
14.15 How Do Geologists Assess the Relative Risks of Different Stretches of Coastline?	426
14.16 What Happens When Sea Level Changes?	428
14.17 What Causes Changes in Sea Level?	430
14.18 CONNECTIONS: What Would Happen to Sea Level if the Ice in West Antarctica Melted?	432
14.19 INVESTIGATION: How Could Global Warming or a Glacial Period Affect North America?	434



**CHAPTER 15:
WEATHERING, SOIL,
AND UNSTABLE SLOPES**

436

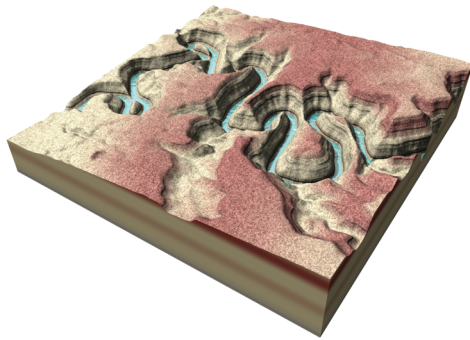
15.1 What Physical Processes Affect Rocks Near the Surface?	438
15.2 How Do Chemical Processes Affect Rocks Near the Surface?	440
15.3 How Do Different Rocks and Minerals Weather?	442
15.4 What Factors Influence Weathering?	444
15.5 How Does Soil Form?	446
15.6 Why Is Soil Important to Society?	448
15.7 What Controls the Stability of Slopes?	450
15.8 How Do Slopes Fail?	452
15.9 How Does Material on Slopes Fall and Slide?	454
15.10 How Does Material Flow Down Slopes?	456
15.11 Where Do Slope Failures Occur in the U.S.?	458
15.12 How Do We Study Slope Failures and Assess the Risk for Future Events?	460
15.13 CONNECTIONS: What Is Happening with the Slumgullion Landslide in Colorado?	462
15.14 INVESTIGATION: Which Areas Have the Highest Risk of Slope Failure?	464



**CHAPTER 16:
STREAMS AND FLOODING**

466

16.1 What Are River Systems?	468
16.2 How Do Streams Transport Sediment and Erode Their Channels?	470



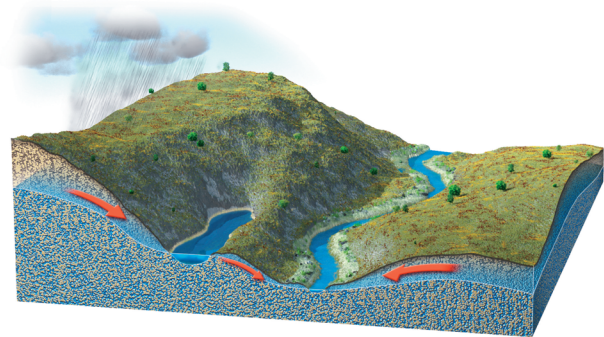
16.3 How Do River Systems Change Downstream or Over Short Time Frames?	472
16.4 What Factors Influence Profiles of Streams?	474
16.5 Why Do Streams Have Curves?	476
16.6 What Features Characterize Mountain Streams?	478
16.7 What Features Characterize Braided Streams?	480
16.8 What Features Characterize Low-Gradient Streams?	482
16.9 What Happens When a Stream Reaches Its Base Level?	484
16.10 How Do Rivers Change Over Time?	486
16.11 What Happens During Stream Incision?	488
16.12 What Is and What Is Not a Flood?	490
16.13 What Were Some Devastating Floods?	492
16.14 How Do We Measure Floods?	494
16.15 CONNECTIONS: How Does the Colorado River Change as It Flows Across the Landscape?	496
16.16 INVESTIGATION: How Would Flooding Affect This Place?	498

CHAPTER 17: WATER RESOURCES

500

17.1 Where Does Water Occur on Our Planet?	502
17.2 How Do We Use Freshwater?	504
17.3 Where Is Groundwater Found?	506
17.4 How and Where Does Groundwater Flow?	508
17.5 What Is the Relationship Between Surface Water and Groundwater?	510
17.6 What Features Form When Groundwater Interacts with Limestone?	512
17.7 How Do We Explore for Groundwater?	514
17.8 What Problems Are Associated with Groundwater Pumping?	516

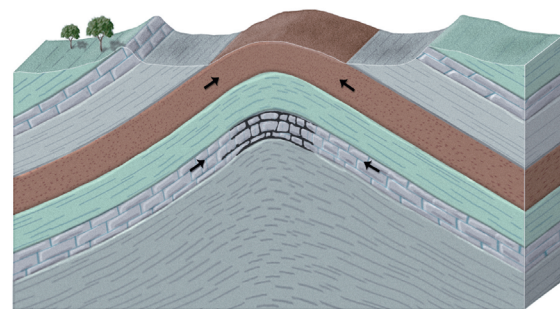
17.9 How Can Water Become Contaminated?	518
17.10 How Does Groundwater Contamination Move and How Do We Clean It Up?	520
17.11 CONNECTIONS: What Is Going On with the Ogallala Aquifer?	522
17.12 INVESTIGATION: Who Polluted Surface Water and Groundwater in This Place?	524



CHAPTER 18: ENERGY AND MINERAL RESOURCES

526

18.1 How Do Oil and Natural Gas Form?	528
18.2 In What Settings Are Oil and Gas Trapped?	530
18.3 How Do Coal and Coal-Bed Methane Form?	532
18.4 What Are Other Types of Hydrocarbons?	534
18.5 How Do We Explore for Fossil Fuels?	536
18.6 How Is Nuclear Energy Produced?	538
18.7 How Is Water Used to Generate Electricity?	540

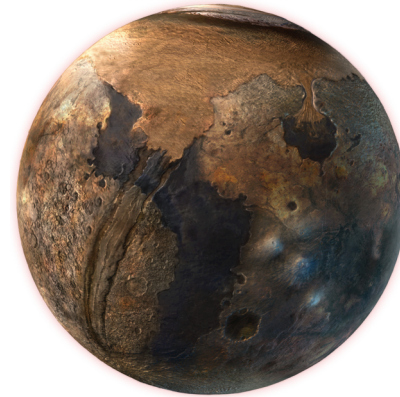


18.8 What Are Alternative Energy Sources?	542
18.9 What Are Mineral Deposits and How Do They Form?	544
18.10 How Do Precious Metal Deposits Form?	546

18.11 How Do Base Metal Deposits Form?	548
18.12 How Do We Explore for Mineral Deposits?	550
18.13 Why Are Industrial Rocks and Minerals So Important to Society?	552
18.14 CONNECTIONS: Why Is Wyoming So Rich in Energy Resources?	554
18.15 INVESTIGATION: Where Would You Explore for Fossil Fuels in This Place?	556

CHAPTER 19: GEOLOGY OF THE SOLAR SYSTEM 558

19.1 How Do We Explore Other Planets and Moons?	560
19.2 Why Is Each Planet and Moon Different?	562
19.3 What Is the Geology of the Inner Planets?	564
19.4 What Is the Geology of Our Moon?	566
19.5 What Is Observed on Jupiter and Its Moons?	568
19.6 What Is Observed on Saturn and Its Moons?	570
19.7 What Is the Geology of the Outer Planets and Their Moons?	572
19.8 CONNECTIONS: What Have We Learned About Mars?	574
19.9 INVESTIGATION: How and When Did Geologic Features on This Alien World Form?	576



Glossary	G-1
Credits	C-1
Index	I-1
Shaded-Relief Map of the United States	I-18
Tapestry of Time Map of North America	Inside Back Cover