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2nd Edition

Geology

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Discover how rocks
change over time

—
Understand what causes
earthquakes, volcanos, and floods

—
Explore the structure
of the Earth

Alecia M. Spooner

Professor of Earth and
Environmental Science



Geology

2nd Edition

by Alecia M. Spooner

for
dummies[®]
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Geology For Dummies®, 2nd Edition

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Contents at a Glance

Introduction	1
Part 1: Studying the Earth	5
CHAPTER 1: Rocks for Jocks (and Everybody Else)	7
CHAPTER 2: Observing Earth through a Scientific Lens	15
CHAPTER 3: From Here to Eternity: The Past, Present, and Future of Geologic Thought	27
CHAPTER 4: Home Sweet Home: Planet Earth	39
Part 2: Elements, Minerals, and Rocks	49
CHAPTER 5: It's Elemental, My Dear: A Very Basic Chemistry of Elements and Compounds	51
CHAPTER 6: Minerals: The Building Blocks of Rocks	61
CHAPTER 7: Recognizing Rocks: Igneous, Sedimentary, and Metamorphic Types	79
Part 3: One Theory to Explain It All: Plate Tectonics	115
CHAPTER 8: Adding Up the Evidence for Plate Tectonics	117
CHAPTER 9: When Crustal Plates Meet, It's All Relative	129
CHAPTER 10: Who's Driving This Thing? Mantle Convection and Plate Movement	149
Part 4: Superficially Speaking: About Surface Processes	163
CHAPTER 11: Gravity Takes Its Toll: Mass Wasting	165
CHAPTER 12: Water: Above and Below Ground	175
CHAPTER 13: Flowing Slowly toward the Sea: Glaciers	195
CHAPTER 14: Blowing in the Wind: Moving Sediments without Water	211
CHAPTER 15: Catch a Wave: The Evolution of Shorelines	223
Part 5: Long, Long Ago in This Galaxy Right Here	233
CHAPTER 16: Getting a Grip on Geologic Time	235
CHAPTER 17: A Record of Life in the Rocks	253
CHAPTER 18: Time before Time Began: The Precambrian	265
CHAPTER 19: Teeming with Life: The Paleozoic Era	281

CHAPTER 20: Mesozoic World: When Dinosaurs Dominated	299
CHAPTER 21: The Cenozoic Era: Mammals Take Over	315
CHAPTER 22: And Then There Were None: Major Extinction Events in Earth's History	333
Part 6: The Part of Tens	345
CHAPTER 23: Ten Ways You Use Geologic Resources Every Day	347
CHAPTER 24: Ten Geologic Hazards	353
Index	359

Table of Contents

INTRODUCTION	1
About This Book	1
Foolish Assumptions	2
Icons Used in This Book	2
Beyond the Book	3
Where to Go from Here	3
PART 1: STUDYING THE EARTH	5
CHAPTER 1: Rocks for Jocks (and Everybody Else)	7
Finding Your Inner Scientist	8
Making observations every day	8
Jumping to conclusions	8
Focusing on Rock Formation and Transformation	8
Understanding how rocks form	9
Tumbling through the rock cycle	9
Mapping Continental Movements	10
Unifying geology with plate tectonics theory	10
Debating a mechanism for plate movements	11
Moving Rocks around on Earth's Surface	11
Interpreting a Long History of Life on Earth	12
Using relative versus absolute dating	12
Witnessing evolution in the fossil record	13
CHAPTER 2: Observing Earth through a Scientific Lens	15
Realizing That Science Is Not Just for Scientists	15
Using a Methodical Approach: The Scientific Method	16
Sensing something new	17
I have a hypothesis!	18
Testing your hypothesis: Experiments	18
Crunching the numbers	19
Interpreting results	21
Sharing the findings	21
Building New Knowledge: A Scientific Theory	21
It's never "just a theory"	22
Scientific theory versus scientific law	22
The road to paradigms	23
Speaking in Tongues: Why Geologists Seem to Speak a Separate Language	23
Lamination vs. foliation: Similar outcomes from different processes	24
Gabbro vs. basalt: Different outcomes from similar processes	24

CHAPTER 3:	From Here to Eternity: The Past, Present, and Future of Geologic Thought	27
	Catastrophe Strikes Again and Again	28
	Early Thoughts on the Origin of Rocks	28
	Developing Modern Geologic Understanding	29
	Reading the rock layers: Steno's stratigraphy	29
	These things take time! Hutton's hypothesis	30
	What has been will be: Lyell's principles	31
	Uniformi-what? Understanding the Earth through Uniformitarianism	32
	Pulling It All Together: The Theory of Plate Tectonics	32
	Forging Ahead into New Frontiers	33
	Asking how, where, and why: Mountain building and plate boundaries	33
	Mysteries of the past: Snowball earth, first life, and mass extinctions	34
	Predicting the future: Earthquakes and climate change	35
	Out of this world: Planetary geology and the search for life	37
CHAPTER 4:	Home Sweet Home: Planet Earth	39
	Earth's Spheres	39
	Examining Earth's Geosphere	41
	Defining Earth's layers	41
	Examining each layer	43
	PART 2: ELEMENTS, MINERALS, AND ROCKS	49
CHAPTER 5:	It's Elemental, My Dear: A Very Basic Chemistry of Elements and Compounds	51
	The Smallest Matter: Atoms and Atomic Structure	52
	Getting to know the periodic table	53
	Interpreting isotopes	56
	Charging particles: Ions	56
	Chemically Bonding	57
	Donating electrons (ionic bonds)	57
	Sharing electrons (covalent bonds)	57
	Migrating electrons (metallic bonds)	58
	Formulating Compounds	60
CHAPTER 6:	Minerals: The Building Blocks of Rocks	61
	Meeting Mineral Requirements	62
	Making Crystals	62

Identifying Minerals Using Physical Characteristics	63
Observing transparency, color, luster, and streak	63
Measuring mineral strength	64
If it tastes like salt, it must be halite: Noting unique mineral properties.	68
Measuring properties in the lab	69
Realizing Most Rocks Are Built from Silicate Minerals	70
Finding silicates in many shapes	71
Grouping silicate minerals	74
Remembering the Nonsilicate Minerals.	74
Carbonates	74
Sulfides and sulfates	75
Oxides	75
Native elements	76
Evaporites	76
Gemstones	77

CHAPTER 7: Recognizing Rocks: Igneous, Sedimentary, and Metamorphic Types 79

Mama Magma: Birthing Igneous Rocks	80
Remembering how magma is made.	80
Classifying melt composition.	81
Reacting in sequence: Bowen’s reaction series.	81
Evolving magmas.	83
Crystallizing one way or another: Igneous rocks	84
Classifying igneous rocks	85
Studying volcanic structures	89
Looking below the surface	92
Merging Many Single Grains of Sand: Sedimentary Rocks	94
Weathering rocks into sediments	95
Changing from sediment into rock.	98
Sizing up the grains: Classifying sedimentary rocks.	99
Searching for sedimentary basins.	102
Telling stories of the past: Sedimentary structures	103
Stuck between a Rock and a Hard Place: Metamorphic Rocks.	106
Turning up the heat and pressure: Metamorphism.	106
Grading metamorphism with index minerals	107
Between the mineral sheets: Foliation, or maybe not.	108
Categorizing metamorphic rocks	110
Tumbling through the Rock Cycle: How Rocks Change from One Type to Another.	112

PART 3: ONE THEORY TO EXPLAIN IT ALL: PLATE TECTONICS	115
CHAPTER 8: Adding Up the Evidence for Plate Tectonics	117
Drifting Apart: Wegener's Idea of Continental Drift	118
Continental puzzle solving	118
Fossil matching	119
Stratigraphic stories	120
Icy cold climates of long ago	122
Meeting at the equator	123
Searching for a mechanism	123
Coming Together: How Technology Sheds Light on Plate Tectonics	124
Mapping the seafloor	124
Flip-flopping magnetic poles: Paleomagnetism and seafloor spreading	125
Measuring plate movements	127
Unifying the theory	127
CHAPTER 9: When Crustal Plates Meet, It's All Relative	129
Density Is Key	130
Two of a Kind: Continental and Oceanic Crust	131
Dark and dense: Oceanic crust	131
Thick and fluffy: Continental crust	131
Understanding Why Density Matters: Isostasy	132
Defining Plate Boundaries by Their Relative Motion	133
Driving apart: Divergent plate boundaries	134
Crashing together: Convergent plate boundaries	136
Slip-sliding along: Transform plate boundaries	139
Shaping Topography with Plate Movements	141
Deforming the crust at plate boundaries	141
Compressing rocks into folds	142
Faulting in response to stress	144
Building mountains	146
CHAPTER 10: Who's Driving This Thing? Mantle Convection and Plate Movement	149
Running in Circles: Models of Mantle Convection	150
Mantle plumes: Just like the lava in your lamp	152
The slab-pull and ridge-push models	152
Using Convection to Explain Magma, Volcanoes, and Underwater Mountains	153
Plate friction: Melting rock beneath the earth's crust	154
Creating volcanic arcs and hotspots	154
Birthing new seafloor at mid-ocean ridges	158

Shake, Rattle, and Roll: How Plate Movements Cause Earthquakes	158
Responding elastically.	159
Sending waves through the earth.	160
Measuring magnitude.	160

PART 4: SUPERFICIALLY SPEAKING: ABOUT SURFACE PROCESSES 163

CHAPTER 11: Gravity Takes Its Toll: Mass Wasting	165
Holding Steady or Falling Down: Friction versus Gravity.	166
Focusing on the Materials Involved	167
Loose materials: Resting at the angle of repose.	167
Bedrock: Losing its stability	168
Triggering Mass Movements	168
Adding water to the mix	168
Changing the slope angle	169
Shaking things up: Earthquakes	170
Removing vegetation	170
Moving Massive Amounts of Earth, Quickly	171
Falls	171
Slides and slumps	171
Flows	172
A More Subtle Approach: Creep and Soil Flow (Solifluction).	173
CHAPTER 12: Water: Above and Below Ground	175
Hydrologic Cycling.	176
Driving the cycle with evaporation	176
Traveling across a continent	177
Streams: Moving Sediments toward the Ocean	178
Draining the basin	178
Two types of flow.	179
Measuring stream characteristics.	180
Carrying a heavy load	180
Measuring what is transported	181
Eroding a Stream Channel to Base Level	182
Seeking Equilibrium after Changes in Base Level.	183
Leaving Their Mark: How Streams Create Landforms	184
Draining the basin	184
Meandering along	185
Depositing sediments along the way	187
Reaching the sea	187

Flowing beneath Your Feet: Groundwater.....	188
Infiltrating tiny spaces underground	188
Measuring porosity and permeability	189
Setting the water table	189
Springing from rocks.....	190
That sinking feeling: Karst, caves, and sinkholes	192
CHAPTER 13: Flowing Slowly toward the Sea: Glaciers	195
Identifying Three Types of Glaciers.....	196
Understanding Ice as a Geologic Force	196
Transforming snow into ice	197
Balancing the glacial budget	197
Flowing solidly down the mountain	198
Eroding at a Snail's Pace: Landforms Created by Glacial Erosion. . .	199
Plucking and abrading along the way.....	200
Creating their own valleys	200
Speaking French: Cirques, arêtes, et roche moutonnées	201
Leaving It All Behind: Glacial Deposits	203
Depositing the till.....	203
Plains, trains, eskers, and kames	204
Behaving erratically: Large boulders in odd places	206
Where Have All the Glaciers Gone?.....	206
Filling the erosional gaps	206
Cycling through ice ages.....	207
Rebounding isostatically.....	209
CHAPTER 14: Blowing in the Wind: Moving Sediments	
without Water.....	211
Lacking Water: Arid Regions of the Earth.....	212
Transporting Particles by Air	212
Skipping right along: Bed load and saltation.....	213
Suspending particles in air.....	214
Deflating and Abrading: Features of Wind Erosion	214
Removing sediments.....	215
Scratching the surface	215
Just Add Wind: Dunes and Other Depositional Wind Features. . . .	216
Migrating piles of sand: Dunes	217
Shaping sand	218
Laying down layers of loess.....	219
Paving the Desert: Deposition or Erosion?	221

CHAPTER 15: Catch a Wave: The Evolution of Shorelines	223
Breaking Free: Waves and Wave Motion	223
Dissecting wave anatomy	223
Starting to roll	224
Going with the flow: Currents and tides	226
Shaping Shorelines	228
Carving cliffs and other features	228
Budgeting to build sandbars	228
Categorizing Coastlines	230
 PART 5: LONG, LONG AGO IN THIS GALAXY RIGHT HERE	 233
CHAPTER 16: Getting a Grip on Geologic Time	235
The Layer Cake of Time: Stratigraphy and Relative Dating	236
Speaking relatively	236
Sorting out the strata	236
Putting rock layers in the right order	237
Losing time in the layers	238
Show Me the Numbers: Methods of Absolute Dating	240
Measuring radioactive decay	241
Common radioactive isotopes for geological dating	244
Other exacting methods of geological dating	245
Relatively Absolute: Combining Methods for the Best Results	248
Eons, Eras, and Epochs (Oh My!): Structuring the Geologic Timescale	249
 CHAPTER 17: A Record of Life in the Rocks	 253
Explaining Change, Not Origins: The Theory of Evolution	254
The Evolution of a Theory	254
Acquiring traits doesn't do it	254
Naturally, selecting for survival	255
Mendel's peas please	255
Genetic nuts and bolts	256
Spontaneously mutating genes	256
Speciating right and left	257
Putting Evolution to the Test	258
Against All Odds: The Fossilization of Lifeforms	259
Bones, teeth, and shell: Body fossils	259
Just passing through: Trace fossils	260
Correcting for Bias in the Fossil Record	261
Hypothesizing Relationships: Cladistics	262

CHAPTER 18: Time before Time Began: The Precambrian	265
In the Beginning . . . Earth's Creation from a Nebulous Cloud	266
Addressing Archean Rocks	267
Creating continents	267
Revving up the rock cycle	267
Feeling hot, hot, hot: Evidence for extreme temperatures	269
Originating with Orogens: Supercontinents of the Proterozoic Eon	270
Single Cells, Algal Mats, and the Early Atmosphere	271
Hunting early prokaryotes and eukaryotes	271
You know it as pond scum: Cyanobacteria	272
Waiting to inhale: The formation of Earth's atmosphere	275
Questioning the Earliest Complex Life: The Ediacaran Fauna	278
CHAPTER 19: Teeming with Life: The Paleozoic Era	281
Exploding with Life: The Cambrian Period	282
Toughen up! Developing shells	282
Ruling arthropods of the seafloor: Trilobites	283
Building Reefs All Over the Place	284
Swimming freely: Ammonoids and nautiloids	285
Exploring freshwater: Eurypterids	287
Spinal Tapping: Animals with Backbones	287
Fish evolve body armor, teeth, and . . . legs?	287
Venturing onto land: Early amphibians	290
Adapting to life on land: The reptiles	290
Planting Roots: Early Plant Evolution	291
Tracking the Geologic Events of the Paleozoic	293
Constructing continents	293
Reading the rocks: Transgressions and regressions	294
Fossilizing carbon fuels	297
Pangaea, the most super of supercontinents	297
CHAPTER 20: Mesozoic World: When Dinosaurs Dominated	299
Driving Pangaea Apart at the Seams	300
One continent becomes many	300
Influencing global climate	301
Creating the mountains of North America	302
Repopulating the Seas after Extinction	303
The Symbiosis of Flowers	304
Recognizing All the Mesozoic Reptiles	306
Flocking together	308

	Climbing the Dinosaur Family Tree	308
	Branching out: Ornithischia and Saurischia	308
	Horned faces and armor: Ornithischian dinosaurs	309
	Long necks and meat eaters: Saurischian dinosaurs	312
	Flocking Together: The Evolutionary Road to Birds	313
	Laying the Groundwork for Later Dominance: Early Mammal Evolution	314
CHAPTER 21:	The Cenozoic Era: Mammals Take Over	315
	Putting Continents in Their Proper (Okay, Current) Places	316
	Creating modern geography	316
	Consuming the Farallon Plate	317
	Carving the Grand Canyon with uplift	319
	Icing over northern continents	320
	Entering the Age of Mammals	320
	Regulating body temperature	322
	Filling every niche	323
	Living Large: Massive Mammals Then and Now	323
	Nosing around elephant evolution	324
	Returning to the sea: Whales	325
	Larger than life: Giant mammals of the ice ages	326
	Right Here, Right Now: The Reign of Homo Sapiens	327
	Arguing for the Anthropocene	329
	Altering the climate	329
	Shaping the landscape	330
	Leaving evidence in the rock record	332
CHAPTER 22:	And Then There Were None: Major Extinction Events in Earth's History	333
	Explaining Extinctions	334
	Heads up! Astronomical impacts	334
	Lava, lava everywhere: Volcanic eruptions and flood basalts	335
	Shifting sea levels	337
	Changing climate	337
	End Times, at Least Five Times	337
	Cooling tropical waters	338
	Reducing carbon dioxide levels	338
	The Great Dying	339
	Paving the way for dinosaurs	340
	Demolishing dinosaurs: The K/T boundary	340
	Modern Extinctions and Biodiversity	342
	Hunting the megafauna	342
	Reducing biodiversity	343

PART 6: THE PART OF TENS	345
CHAPTER 23: Ten Ways You Use Geologic Resources	
Every Day	347
Burning Fossil Fuels	347
Playing with Plastics	348
Gathering Gemstones.....	348
Drinking Water.....	349
Creating Concrete	349
Paving Roads	350
Accessing Geothermal Heat.....	350
Fertilizing with Phosphate	350
Constructing Computers	351
Building with Beautiful Stone	351
CHAPTER 24: Ten Geologic Hazards	353
Changing Course: River Flooding	353
Caving In: Sinkholes	354
Sliding Down: Landslides	354
Shaking Things Up: Earthquakes.....	355
Washing Away Coastal Towns: Tsunamis	355
Destroying Farmland and Coastal Bluffs: Erosion	356
Fiery Explosions of Molten Rock: Volcanic Eruptions.....	356
Melting Ice with Fire: Jokulhlaups	357
Flowing Rivers of Mud: Lahars.....	357
Watching the Poles: Geomagnetism.....	358
INDEX	359

Introduction

Geology is the study of the earth. By default this means that geology is a vast, complex, and intricate topic. But “vast, intricate, and complex” does not necessarily mean difficult. Many folks interested in geology just don’t know where to start. Minerals? Rocks? Glaciers? Volcanoes? Fossils? Earthquakes? The sheer number of topics covered under the heading “geology” can be overwhelming.

Enter *Geology For Dummies!* The goal of this book is to break through the overwhelming array of geology information and provide a quick reference for key concepts in the study of the earth.

My hope is that you find this book both interesting and useful, whether you’ve purchased it to accompany a course you’re taking in school or to help you find answers to questions you have about the planet you live on.

About This Book

In *Geology For Dummies*, you can start anywhere. This book is written as an introduction to the most common topics in geology. Follow your interest from one topic to the next, or start at the beginning and read the chapters in order. I wrote the book in a style that allows you to open to any page and learn something. But if you want to start at the beginning, you’re introduced to the concepts in a logical and structured order that (I hope!) answers your questions almost as soon as you ask them.

Throughout the book you find cross-references to other chapters. I use them because it’s impossible to explore one topic in geology without touching on many others. The multiple cross-references weave together the different parts of geologic study into a complex whole.

Wherever possible, I include illustrations to accompany my explanations. Geology is all around you, so while you are busy reading this book and examining the illustrations, I encourage you to also look around and find real-world examples of the processes and features I describe. To this end, I have also included a color photo section in the middle of the book featuring vivid images that help bring the subject matter to life.

Foolish Assumptions

As I was writing this book, I had to make a few assumptions about you, the reader. I assume that you live on Earth and are familiar with rocks, streams, and weather (rain, wind, and sun). I also assume that you are familiar with a very basic geography of the earth, including the continents, oceans, and major mountain ranges.

I do not assume that you have any scientific background in chemistry, which you may find useful if you want to dig deeper into the details of rock formation and transformation. Similarly, when I discuss evolution I do not assume that you have any background in biology or anatomy (and none is needed to understand the concepts I present). If the subject of evolution interests you, you may find that your questions lead you to pick up other reference books on that topic.

If you find that your interest in geology is further fueled by this book, I recommend that you purchase an earth science or geology dictionary. Geology is full of terms with precise and informative meanings. With this kind of dictionary on hand, you'll find you can easily interpret even the most befuddling geological explanations.

Icons Used in This Book

Throughout this book, I use icons to draw your attention to certain information:



TIP

The Tip icon indicates information that may be especially useful to you as you prepare for a geology exam or assignment or as you begin studying geology on your own.



WARNING

This icon, which appears only rarely in this book, points out situations that may be dangerous.



REMEMBER

Information highlighted with the Remember icon is foundational to understanding the concept being explained. Sometimes this icon indicates a definition or concise explanation. Other times it indicates information that will help you tie multiple concepts together.



TECHNICAL
STUFF

This icon indicates that the information goes a little beyond the surface into some technical details. These details are not necessary for your broad understanding of the topic or concepts, but you may find them interesting and informative.

Beyond the Book

In addition to what you're reading right now, this product also comes with a free access-anywhere Cheat Sheet that tells you about plate tectonics and the geologic timescale.. To get this Cheat Sheet, simply go to www.dummies.com and type **Geology For Dummies Cheat Sheet** in the Search box.

Where to Go from Here

You have most likely purchased this book with a question about geology already in mind. In that case, I encourage you to follow your interest. Use the table of contents or index to find where I answer your question, flip to that page, and get started!

If you don't have a particular question in mind, here are a few of my favorite topics that will get you started on your study of Earth:

- » **Chapter 8, "Adding Up the Evidence for Plate Tectonics":** In this chapter, I tell you the story of how an early geologist, Alfred Wegener, began to think about plate movements. He collected evidence to support his ideas, but it took many years before the idea of plate tectonics was accepted by the scientific community. This chapter is a great introduction to how science really happens, as well as an overview of the foundational theory of modern geology.
- » **Chapter 12, "Water: Above and Below Ground":** If you want to get started by reading about something you can relate to, start with flowing water. Streams and rivers are the most common geologic processes on Earth. Regardless of where you live, you have probably witnessed the action of flowing water moving sediment or rocks. This chapter provides details from how water picks up and carries particles, to how rivers carve canyons and caves. It also covers the topic of groundwater, which is where most of the water you drink comes from.
- » **Chapter 18, "Time before Time Began: The Precambrian":** Long ago in Earth's deep, dark, murky past lay the beginnings of life. This chapter describes the first few billion years of Earth's existence, from its formation from a gaseous cloud, up to and including the earliest evidence for life — in the form of trace fossils called *stromatolites*.

1

Studying the Earth

IN THIS PART . . .

Discover you are already a scientist, asking questions and seeking answers every day!

Learn the history and development of geologic study.

Go on a guided tour of Earth's systems, from the atmosphere to the inner core and everything in between.

IN THIS CHAPTER

- » Discovering the scientific study of Earth
- » Learning how rocks transform through the rock cycle
- » Putting together plate tectonics theory
- » Recognizing surface processes
- » Exploring Earth's history

Chapter **1**

Rocks for Jocks (and Everybody Else)

Geology and earth sciences seem to have a reputation for being easy subjects, or at least the least difficult of the science courses offered in high school and college. Perhaps that's because the items observed and studied in geology — rocks — can be held in your hand and seen without a microscope or telescope, and they can be found all around you, anywhere that you are.

However, exploring geology is not just for folks who want to avoid the heavy calculations of physics or the intense labs of chemistry. Geology is for everyone. Geology is the science of the planet you live on — the world you live in — and that is reason enough to want to know more about it. *Geology* is the study of the earth, what it's made of, and how it came to look the way it does. Studying geology means studying all the other sciences, at least a little bit. Aspects of chemistry, physics, and biology (just to name a few) are the foundation for understanding Earth's geologic system, both the processes and the results.

Finding Your Inner Scientist

You are already a scientist. Maybe you didn't realize this, but just by looking around and asking questions you behave just like a scientist. Sure, scientists call their approach of asking and answering questions the *scientific method*, but what you do every day is the very same thing, without the fancy name. In Chapter 2, I present the scientific method in detail. Here, I offer a quick overview of what it entails.

Making observations every day

Observations are simply information collected through your five senses. You could not move through the world without collecting information from your senses and making decisions based on that information.

Consider a simple example: Standing at a crosswalk, you look both ways to determine if a car is coming and if the approaching car is going slow enough for you to safely cross the street before it arrives. You have made an observation, collected information, and based a decision on that information — just like a scientist!

Jumping to conclusions

You constantly use your collected observations to draw conclusions about things. The more information you collect (the more observations you make), the more solid your conclusion will be. The same process occurs in scientific exploration. Scientists gather information through observations, develop an educated guess (called a *hypothesis*) about how something works, and then seek to test their educated guess through a series of experiments.

No scientist wants to jump to a false conclusion! Good science is based on many observations and is well-tested through repeated experiments. The most important scientific discoveries are usually based on the educated guesses, experiments, and continued questioning of a large number of scientists.

Focusing on Rock Formation and Transformation

As I explore in detail in Part 2 of this book, the foundation of geology is the examination and study of rocks. Rocks are, literally, the building blocks of the earth and its features (such as mountains, valleys, and volcanoes). The materials that make

up rocks both inside and on the surface of the earth are constantly shifting from one form to another over long periods of time. This cycle and the processes of rock formation and change can be traced through observable characteristics of rocks found on Earth's surface today.

Understanding how rocks form

Characteristics of rocks such as shape, color, and location tell a story of how and where the rocks formed. A large part of geologic knowledge is built on understanding the processes and conditions of rock formation. For example, some rocks form under intense heat and pressure, deep within the earth. Other rocks form at the bottom of the ocean after years of compaction and cementation. The three basic rock types, which I discuss in detail in Chapter 7, are:

- » **Igneous:** Igneous rocks form as liquid rock material, called *magma* or *lava*, cools. Igneous rocks are most commonly associated with volcanoes.
- » **Sedimentary:** Most sedimentary rocks form by the cementation of sediment particles that have settled to the bottom of a body of water, such as an ocean or lake. (There are also some sedimentary rocks, which are not formed this way. I describe these in Chapter 7 as well.)
- » **Metamorphic:** Metamorphic rocks are the result of a sedimentary, igneous, or other metamorphic rock being squeezed under intense amounts of pressure or subjected to high amounts of heat (but not enough to melt it) that change its mineral composition.

Each rock exhibits characteristics that result from the specific process and environmental conditions (such as temperature, or water depth) of its formation. In this way, each rock provides clues to events that happened in Earth's past. Understanding the past helps us to understand the present and, perhaps, the future.

Tumbling through the rock cycle

The sequence of events that change a rock from one kind into another are organized into the rock cycle. It is a cycle because there is no real beginning or end. All the different types of rocks and the various earth processes that occur are included in the rock cycle. This cycle explains how materials are moved around and recycled into different forms on the earth's surface (and just below it). When you have a firm grasp on the rock cycle, you understand that every rock on Earth's surface is just in a different phase of transformation, and the same materials may one day be a very different rock!

Mapping Continental Movements

Most of the rock-forming processes of the rock cycle depend on forces of movement, heat, or burial. For example, building mountains requires force exerted in two directions, pushing rocks upward or folding them together. This type of movement is a result of continental plate movements. The idea that the surface of the earth is separated into different puzzle-like pieces that move around is a relatively new concept in earth sciences, called *plate tectonics theory* (the subject of Part 3).

Unifying geology with plate tectonics theory

For many decades, earth scientists studied different parts of the earth without knowing how all the features and processes they examined were tied together. The idea of plate movements came up early in the study of geology, but it took a while for all the persuasive evidence to be collected, as I describe in Chapter 8.

By the middle of the twentieth century, scientists had discovered the Mid-Atlantic Ridge and gathered information about the age of sea floor rocks across the ridge. With this evidence they proposed the theory of plate tectonics suggesting the earth's crust is broken into pieces, or plates. Where two plates touch and interact is called a *plate boundary*.

Exactly how the earth's crustal plates interact is determined by the type of motion and type of crustal material. These interactions are described as plate boundary types and include:

- » **Convergent boundaries:** At convergent boundaries, two crustal plates are moving toward one another and come together. Depending on the density of the crustal plates, this collision builds mountains, or causes plate *subduction* (meaning one plate goes beneath another), producing volcanoes.
- » **Divergent boundaries:** At divergent plate boundaries, two crustal plates are separating or moving apart from one another. These boundaries are most commonly observed along the sea floor, where the upwelling of magma along the boundary creates a mid-ocean ridge, but they may also occur on continents, such as in the African rift valley.
- » **Transform boundaries:** At transform boundaries, the two plates are neither colliding nor separating; they are simply sliding alongside one another.

In Chapter 9, I provide the details on the different characteristics of continental plates and how they interact as they move around Earth's surface, including the particular geologic features associated with each plate boundary type.

Debating a mechanism for plate movements

While the unifying theory of plate tectonics has been well-accepted by the scientific community, geologists have yet to agree on what, exactly, drives the movement of continental plates.

Three dominant forces are thought to work together to drive plate tectonic motion:

- » **Mantle convection:** The *convection* of the mantle — the movement of heated rock materials beneath Earth's crust is thought to be the dominant driver of plate motion. Mantle rock moves outward towards the crust when it is heated, and then cools and sinks back towards the core (sort of like the wax in a lava lamp). As it moves, the crustal plates resting on the outer mantle are carried along.
- » **Ridge-push:** The ridge-push force is a result of new crustal rock forming at a mid-ocean ridge. The addition of new crust at the plate edge will push the plate away from the ridge and towards the plate boundary along its outer or opposite edge.
- » **Slab-pull:** As the ridge is pushing the plate away, the outer edge of such a plate will be sinking into the mantle, and as this slab sinks, it pulls the plate along behind it — creating the slab-pull force.

Mantle convection, ridge-push, and slab-pull forces work together to drive plate tectonic motion. In Chapter 10, you will find more details on how these three forces are constantly reshaping the surface of the earth.

Moving Rocks around on Earth's Surface

On a smaller than global scale, rocks are constantly being moved around on Earth's surface. Surface processes in geology include changes due to gravity, water, ice, wind, and waves. These forces sculpt Earth's surface, creating landforms and landscapes in ways that are much easier to observe than the more expansive

processes of rock formation and tectonic movement. Surface processes are also the geologic processes humans are more likely to encounter in their daily lives.

- » **Gravity:** Living on Earth you may take gravity for granted, but it is a powerful force for moving rocks and sediment. Landslides, for example, result when gravity wins over friction and pulls materials downward. The result of gravity's pull is *mass wasting*, which I explain in Chapter 11.
- » **Water:** The most common surface processes include the movement of rocks and sediment by flowing water in river and stream channels. The water makes its way across Earth's surface, removing and depositing sediment, reshaping the landscape as it does. The different ways flowing water shapes the land are described in Chapter 12.
- » **Ice:** Similar to flowing water but much more powerful, ice moves rocks and can shape the landscape of an entire continent through glacier erosion and deposition. The slow-flowing movement of ice and its effect on the landscape are described in Chapter 13.
- » **Wind:** The force of wind is most common in dry regions, and you are probably familiar with the landforms it creates, called *dunes*. You may not realize that the speed and direction of wind create many different types of dunes, which I describe in Chapter 14.
- » **Waves:** Along the coast, water in the form of waves is responsible for shaping shorelines and creating (or destroying) beaches. In Chapter 15, I describe in detail the various coastal landforms created as waves remove or leave behind sediments.

Interpreting a Long History of Life on Earth

One of the advantages of studying geology is being able to learn what mysteries of the past are hidden in the rocks. Sedimentary rocks, formed layer by layer over long periods of time, tell the story of Earth's living history: changing climates and environments, as well as the evolution of life from single cells to modern complexity.

Using relative versus absolute dating

Scientists use two approaches to determine the age of rocks and rock layers: relative dating and absolute dating.

Relative dating provides ages of rock layers in relation to one another — for example, stating that one layer is older or younger than another is. The study of rock layers, or *strata*, is called *stratigraphy*. In methods of relative dating, geologists apply *principles of stratigraphy* such as these:

- » Rock layers below are generally older than rock layers above.
- » All sedimentary rock layers are originally formed in a horizontal position.
- » When a different rock is cutting through layers of rock, the cross-cutting rock is younger than the layers it cuts through.

These principles and a few others that I describe in Chapter 16 guide geologists called *stratigraphers* in interpreting the order of rock layers so that they can form a relative order of events in Earth's history.

However, sometimes simply knowing that something is older than — or younger than — something else is not enough to answer the question being asked. *Absolute dating* methods use radioactive atoms called *isotopes* to determine the age in numerical years of some rocks and rock layers. Absolute dating methods may determine, for example, that certain rocks are 2.6 million years old. These methods are based on the knowledge, learned from laboratory experiments, that some atoms transform into different atoms at a set rate over time. By measuring these rates of change in a lab, scientists can then measure the amount of the different atoms in a rock and provide a fairly accurate age for its formation.

If the process of obtaining absolute dates from isotopes seems very complex, don't worry: In Chapter 16, I explain in much more detail how absolute dates are calculated and how they are combined with relative dates to construct the *geologic timescale*: a sequence of Earth's geological history separated into different spans of time (such as periods, epochs, and eons).

Witnessing evolution in the fossil record

The most fascinating story told in the rock layers is the story of Earth's evolution. To *evolve* simply means to change over time. And indeed, the earth has evolved in the 4.5 billion years since it formed.

Both the earth itself and the organisms that live on Earth have changed through time. In Chapter 17, I briefly explain the biological understanding of evolution. Much of modern understanding about how species have changed through time is built on evidence from *fossilized* or preserved life forms in the rock layers.

Fossilization occurs through different geologic and chemical processes, but all fossils can be described as one of two forms:

- » **Body fossils:** Remains of an organism itself, or an imprint, cast, or impression of the organism's body.
- » **Trace fossils:** Remains of an organism's activity, such as movement (a footprint) or lifestyle (a burrow) but without any indication of the organism's actual body.

Earth did not always support life. In Chapter 18, I describe the very early Earth as a lifeless, hot, atmosphere-free planet in the early years of the solar system's formation. It took billions of years before simple, single-celled organisms appeared, and their origins are still a scientific mystery.

Simple, single-celled life ruled Earth for many millions of years before more complex organisms evolved. Even then, millions of years passed with soft-bodied life forms that are difficult to find in the fossil record. It wasn't until 520 million years ago that the *Cambrian explosion* occurred. Chapter 19 describes this sudden appearance of shell-building, complex life as well as the millions of years that followed when life was lived almost entirely in the oceans until amphibians emerged on the land.

Chapter 20 delves into the Age of Reptiles, when dinosaurs ruled the earth and reptiles filled the skies and seas. During this period, all the earth's continents were connected as Pangaea, Earth's most recent supercontinent. But before the Age of Reptiles ended, Pangaea broke apart into the separate continents you recognize today. Evidence for Pangaea is still visible in the coastal outlines of South America and Africa — indicating where they used to be attached as part of the supercontinent.

In relatively recent time, geologically speaking, mammals took over from reptiles to rule the earth. The Cenozoic era (beginning 65.5 million years ago), which we are still experiencing, is the most recent and therefore most detailed portion of Earth's history that can be studied in the geologic record (the rocks). Many of the most dramatic geologic features of the modern Earth, such as the Grand Canyon and the Himalayan Mountains, were formed in this most recent era. In Chapter 21, I describe the evolution of mammal species (including humans) and the geologic changes that occurred to bring us to today.

At various times in the history of Earth, many different species have disappeared in what scientists call *mass extinction events*. In Chapter 22, I describe the five most dramatic extinction events in Earth's history. I also explain a few of the common hypotheses for mass extinctions, including climate change and asteroid impacts. Finally, I explain how the earth may be experiencing a modern-day mass extinction due to human activity.