An Introduction to Geology and Geologic Maps: Background for Understanding the Geology of the Middlesex Fells Reservation, Massachusetts

by

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Cover image: View of the city of Boston from the top of Boojum Rock in the southern Middlesex Fells. Image taken in 2012.

PREFACE

This part of the book introduces you to the project at Tufts University to make geologic maps of the Middlesex Fells Reservation. It gives my motivations for mapping the Fells and the importance of understanding the geology of this area. This preface explains what starting knowledge you must have to understand the fundamental geological science that is discussed in the following chapters. At the end of this section are acknowledgments to people who helped along the way.

Jack Ridge, August 30, 2021
Tufts University

WHY STUDY GEOLOGY?

Do you like to solve puzzles? Or have you ever wanted to travel back in time, not only to the time of your great grandparents, or other distant relatives, but into the deep past? I mean back to the last ice age, or long before the time of humans, or when long extinct organisms inhabited the planet, perhaps even before there were plants on land or animals with shells and skeletons, back deep into Earth's history. Geologists take this journey every day! In my case, I get to visit the northeastern United States during the last ice age or visit the 600-million-year-old terrane of the Boston area through the rocks and other geologic features I study. I decipher the clues we find in rocks and other geologic features and try to understand Earth's vast history in detail. When I look at rocks, I feel like I'm solving a giant puzzle. It is challenging and fun, and at the same time it is a useful contribution to understanding local geologic history and how Earth's systems operate.

A Message for Educators, Politicians and Other Concerned Citizens

How many people understand very much about Earth's history and make up? Very few! **Why does this matter?** We interact with and rely on geology, or Earth science, our whole lives, and we should spend some time getting to know how our environment operates and how our planet was formed. This is the system we count on for survival. It includes the air we breathe, the water we drink, the nutrients for our food, our energy and other natural resources, and the surface we live on. It has become essential with a growing world population and finite resources to understand how these systems operate so we can inhabit our planet wisely. Geology defines who we are and how we got here. And yet, Earth science, or geology, struggles to maintain a place in school curriculums, even though it impacts us every day.

Geology is a subject that is very accessible in terms of teaching and understanding the fundamental natural science necessary to understand how our planet operates. It is a science governed by the principles of chemistry, physics, biology, and mathematics with a dose of history, usually very ancient history, thrown in. Most people don't appreciate geology's complexity or know how scientists deal with the subject, which is something that is not hard to appreciate or learn with a few observations.

My Experience

As a geologist, I get excited about studying Earth's past and how it operates. I learn something new about the planet every day. My career as a geologist has felt like the Magic School Bus on steroids. It is impossible to sit in a room with my colleagues for even 5 minutes and not come away knowing something new about Earth or other planets in our solar system. I had my natural curiosity for the planet cemented by my parents, and especially my grandfather, who were always curious about nature. My grandfather was always up for a fishing trip, a hike in the woods, or picking wild blueberries. He lived in the coal regions of eastern Pennsylvania (Minersville, Pennsylvania) and took me on many hikes through the old spoils of open-pit coal mines. We collected pyrite crystals (fool's gold) and fossils of trees and plants that were 320 million years old. I was hooked! Though I didn't appreciate it at the time, this was also my first exposure to a place where there was tremendous pollution, subsurface fires, and land surface scars left by coal mining. Humans had not been good stewards of our planet.

OBJECTIVES IN WRITING THIS BOOK

The main objective in making a geologic map of the Middlesex Fells Reservation is to provide detailed information on the geology that is not only a contribution for the geologic academic community but is also accessible to the general public. Geology is not only interesting but fun. To make the geologic history and map understandable to the general public, I have written this book as an introduction to geology. It provides information to those who have never taken a geology course in school and have had very little introduction to Earth science. If you had a very good high school Earth science course, a rarity these days, or have taken an introductory geology course in college and remember its content, much of this general discussion will be a familiar. Unfortunately, most middle and high school science courses that include some Earth science are not adequate for immediately understanding the geologic maps and history of the Fells. In fact, nowadays it would be hard to find a comprehensive Earth science course in high school or even a college course that would immediately allow you to understand the geology of the Fells. You would have to supplement your knowledge with more detailed information. This introductory book should provide enough background information to make the more detailed discussion and map of the Fells geology understandable and more enjoyable. I recommend that you refer to this book as a starting point. The map and its description can be found at: Bedrock Geology of the Middlesex Fells Reservation, MassachusettsThe Geology of the Middlesex Fells (tufts.edu)

In addition to satisfying my own curiosity, my exploration of the Fells will hopefully transfer my enthusiasm and curiosity to more people, especially to children, in order to give them an appreciation of the special place our planet represents. I hope other people will find learning about the geology of the Fells as interesting, exciting and fun as I do.

GETTING STARTED

There are some fundamental things that you will have to know to understand some introductory geology that are not explained in this book. These are simple things that we encounter in everyday life, or that we study in elementary through high school. They are listed below.

1. You will have to know left from right and what clockwise and counterclockwise mean.

2. You will have to know the meaning of directions such as north, east, southwest, etc.

3. You should know the meaning of horizontal and vertical. Note that horizontal is different than flat. A flat surface can be either horizontal, vertical, or tilted at any angle in between.

4. You must know how to read a ruler or a map in metric units. All scientists use metric units, and geology is no exception. We frequently make measurements in centimeters (cm) and millimeters (mm) when measuring features in rocks or talk about the thicknesses of geologic units in meters (m). We measure land surface distances in meters (m) and kilometers (km). We often refer to microscopic lengths in microns (µm). 1 mm = 1000 µm and 0.001 (or 1/1000) mm = 1 µm. We record temperatures in degrees Celsius (°C). To convert between °C and °F: °C = (5/9)°F - 32° or °F = (9/5)°C + 32°.

5. You will have to know how to calculate a percentage and what it means.

6. You will have to know how to read a graph, i.e., understand what an axis on a graph means, how to plot points on a graph, and what lines on a graph represent.

7. You will have to know the order of arithmetic operations in simple equations. Operations that are in a set of parentheses (P) must be done first following the order of operations: multiplication (M), division (D), addition (A) and then subtraction (S). After the parentheses have been cleared, this same order of operations is used to complete the rest of the calculations. Always in this order!!! (Remember: "**P**lease **M**y **D**ear **A**unt **S**ally" or **PMDAS**.) For example, try solving the following equation:

(6 / 2 + 5 x 6 - 4) x 3 + 2/2.

You will get a very different answer if you do things out of order!

Answer:
[Clear parentheses in the first part of the equation by doing the math operations in MDAS order: (6 / 2 + 5 x 6 - 4) = (6 / 2 + 30 - 4) = (3 + 30 - 4) = (33 - 4) = 29. Then complete the rest of the equation with the correct order for math operations: 29 x 3 + 2 / 2 = 87 + 2 / 2 = 87 + 1 = 88.]

8. Geology is full of both very large and very small numbers. You should become familiar with scientific notation, where numbers are expressed as a power or multiple of 10, where 1 = 10^0, 10 = 10^1, 100 = 10^2, 1000 = 10^3, 1 million = 10^6, and 1 billion = 10^9, 4 billion = 4 x 10^9, etc. Also, for numbers less than one: 0.1 or 1/10 is $1/10^1 = 10^{-1}$, 0.01 or 1/100 is $1/10^2 = 10^{-2}$, 0.001 or 1/1000 is $1/10^3 = 10^{-3}$, and 1 millionth = $1/10^6$ or 10^{-6}. It saves writing lots of zeros, and it is the standard way of expressing large or small numbers in science.

9. You will also have to become familiar with some of the abbreviations of chemical elements on the periodic table of the elements. Most of what you will learn in this book focuses on the lighter elements on the upper half of the periodic table with a little lead and uranium thrown in. These element symbols will be introduced as you progress through the book.

There are several conventions used in this book. Like all pieces of scientific writing, it is important to recognize the sources of information in the text that are the findings of people who have authored papers or books on the subject and are the first to state or discover something. (Imagine if politicians had to do this!) This is true of all information that goes beyond the commonly accepted knowledge of the scientific community. For example, I can state that the chemical composition of quartz is silicon dioxide without a reference to another scientist's work because it is understood that this is true, and it appears in every introductory textbook on geology without references. I'm not even sure who the first person was that determined the chemical composition of quartz. It has been known for a very long time and it might not be known who first identified quartz's composition. By definition: quartz is silicon dioxide. However, it is not general knowledge that a rock unit in the Fells called the Medford Dike has abundant microscopic crystals of a phosphate mineral called apatite. I must give a reference to the paper, where this was first published, unless I discovered this for the first time on my own and I am revealing the results of my observations here for the first time. Statements of fact that are credited to other publications are cited in the text by the author(s) and year of the publication. At the end of each chapter each citation of this type is listed alphabetically in the "References" section. This format is commonly used in geological and other science research journals and books. Few science publications, unless popular commercial books (not a textbook or scientific journal), use footnotes as references like is done in history books.

ACKNOWLEDGMENTS AND THANKS

Making geologic maps and writing about them is an intense activity that draws on knowledge acquired over many years of field experience, countless hours of confusion, and many discussions (and sometimes arguments) with other geologists, especially those at Tufts and in the Boston area. There are many "what if" scenarios that turn into friendly lunchtime discussions injected with tremendous humor. In this regard, I would like to thank Jim Hume, Charlie Stearns, Anne Gardulski, Jake Benner, Molly McCanta, Grant Garven, Andrew Kemp, Noel Heim and Jill VanTongeren, who were or are colleagues of mine at Tufts. They all provided insights into various aspects of geology. Gratitude also goes to the students at Tufts who over the years have asked what they thought were stupid questions that turned out to be pivotal to understanding key issues. There are no stupid questions!

Bert Reuss, my colleague and teaching mentor at Tufts, deserves special thanks. Bert has given me many insights about the local geology and spent countless hours with me over the years in trying to make sense of the rocks in the Fells. His desire to not only explain, but to have you understand something, makes him an excellent teacher to not only his students over almost 40 years at Tufts (1969-2008), but also his friends and colleagues.

Every geologist has mentors who instilled appreciation and enjoyment for the science. In my case it was two graduate thesis advisors: Edward Evenson at Lehigh University and Ernest Muller at Syracuse. At Syracuse, my exposure to John S. Dickey gave me an appreciation of geology outside my area of expertise in glacial geology while instilling a sense of humor and fun in the science.

There are also many colleagues at other schools that I owe recognition, one of whom stands out when trying to understand local geology. Meg Thompson has published many professional papers on the geology of the Boston area, which have progressed our understanding of the geologic history of the Boston Basin. Although she has retired from teaching at Wellesley College, she continues to push the frontiers of what we know about Boston geology. Lindley Hanson (Salem State College) and Francis MacDonald (Harvard University, now at Univ. California Santa Barbara), and Richard Bailey and Martin Ross (Northeastern University) have also provided friendly discussions and field trips that furthered my understanding of local geology.

Special thanks goes to Lara Williams, who reviewed early editions of the manuscript and endured my truly perplexing use of commas.