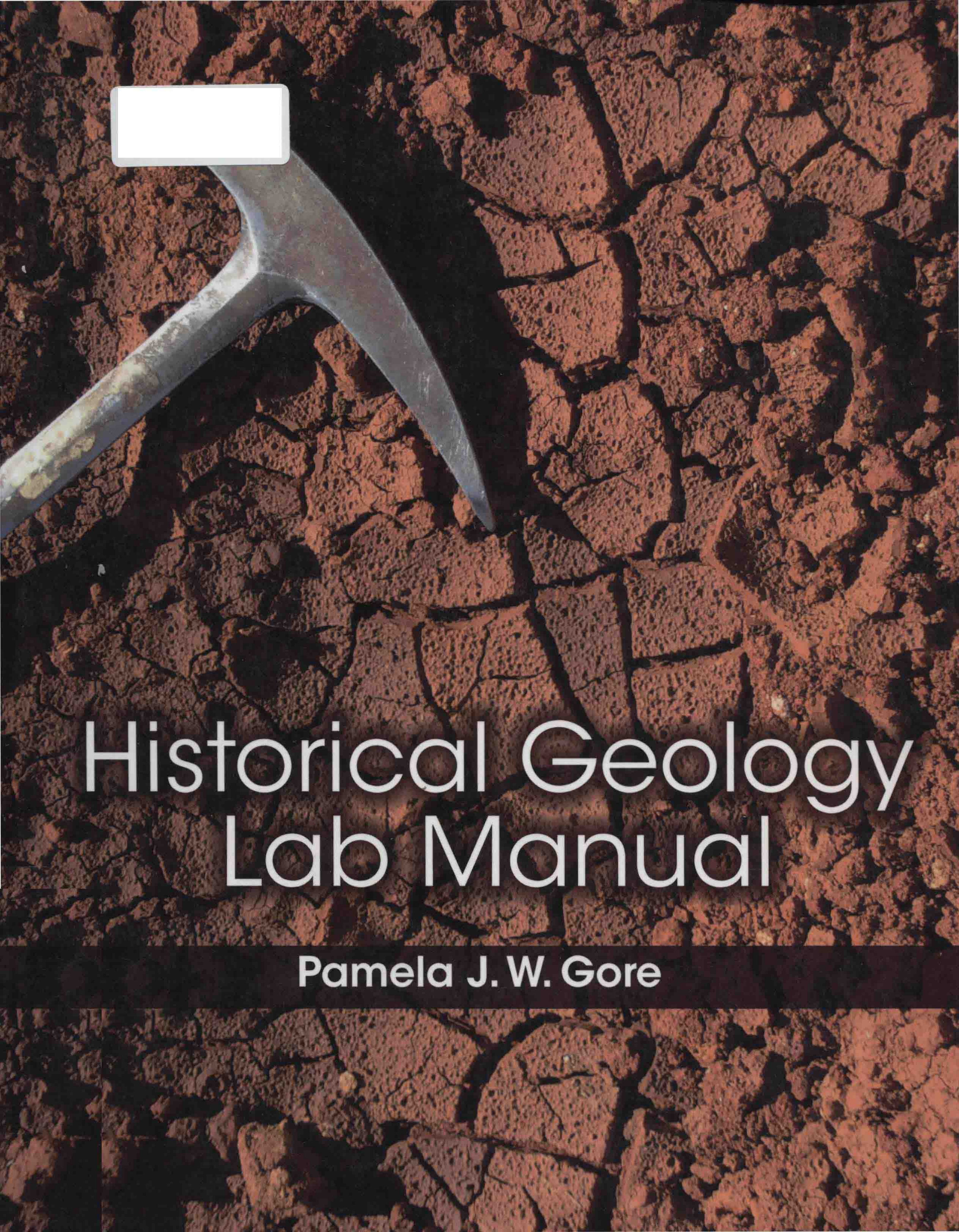


Historical Geology Lab Manual

Pamela J. W. Gore

HISTORICAL GEOLOGY

LAB MANUAL

Pamela J. W. Gore
Georgia Perimeter College

WILEY

VP & PUBLISHER: Petra Recter
EXECUTIVE EDITOR: Ryan Flahive
ASSISTANT EDITOR: Julia Nollen
EDITORIAL ASSISTANT: Kathryn Hancox
MARKETING MANAGER: Suzanne Bochet
PHOTO EDITOR: Elizabeth Blomster
DESIGNER: Kenji Ngieng
ASSOCIATE PRODUCTION MANAGER: Joyce Poh

This book was set by Laserwords Private Limited. Cover and text printed and bound by Courier Digital Solutions.

This book is printed on acid free paper.

ISBN 978-1-118-05752-0 (paperback)

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

HISTORICAL GEOLOGY

LAB MANUAL

Preface

This laboratory manual is designed for introductory geology students with no prior geology coursework. The chapter on Relative Dating gives the student experience with using basic geologic principles for determining the sequence of geologic events, a topic that is typically presented in the first few chapters of historical geology lecture textbooks. The chapter on Rocks and Minerals provides a quick introduction to the minerals and rocks most commonly encountered in a first geology course, as ell as a quick review for students who have previously completed physical geology lab. Subsequent labs deal with Rock Weathering and Interpretation of Sediments, Sedimentary Rocks, and Sedimentary Structures. Students learn to interpret processes acting in the depositional basin, and then they interpret Depositional Sedimentary Environments based on rock types and sedimentary structures. Students also learn Stratigraphy and Lithologic Correlation and how to interpret sea-level change in the rock record.

The last five labs deal with fossils and include an overview of the latest classification system. These labs cover Microfossils and Introduction to the Tree of Life, Invertebrate Macrofossils and Classification of Organisms, Fossil Preservation and Trace Fossils, and two web quests: Fossils on the Internet, and The Evolution of the Vertebrates.

This laboratory manual has evolved over time from labs that I began writing as a graduate student at George Washington University in the early 1980s. I was teaching Historical Geology labs and did not find that any of the lab manuals fit my style of teaching and goals for the course. I wanted students to have a strong hands-on experience with geologic specimens and I wanted them to have fill-in charts where they could record their observations and interpretations on pages that they could submit for grading without having answers interspersed throughout the lab. The lab manual needed to be accessible to nonscience majors and also provide a strong background for Geology majors and other science majors. It is important for students to learn that they can think and make interpretations, and not just memorize vocabulary. I wanted concepts that carried over from one lab to the next, and labs that reinforced and built on previous labs, so that at the end of the semester, the students would have some experience at interpreting the rock record and some understanding of how the process of science works. I extend my appreciation to the students and faculty at George Washington University in the early 1980s (including Roy Lindholm, Tony Coates, John Lewis, David Govoni, and the late George Stephens) for inspiring and encouraging my early efforts.

I revised and updated the labs many times over the years while a Professor of Geology at Georgia Perimeter College (GPC), receiving comments, criticisms, and suggestions from students and Geology faculty colleagues (including Lynn Zeigler, Polly Bouker, Deniz Ballero, Kimberly Schulte, Gerald Pollack, Dion Stewart, John Anderson, Ed Albin, Rick Nixon, Debia McCulloch and others), as well as colleagues at other institutions in Georgia and across the country. In 1998, former student Gwendolyn Rhodes scanned my original artwork to help me get the lab manual online. The lab manual was available online for a number of years, and colleagues at colleges, universities, and schools around the world used all or parts of it with their classes.

As a result, I received emails from a worldwide audience including students and faculty in places such as Mauritius, Japan, Egypt, Morocco, Indonesia, Chile, Saudi Arabia, the Philippines, Oman, Iran, Iraq, Hong Kong, Belgium, Scotland, Ireland, England, Wales, Canada, Vietnam, Thailand, Brazil, Nigeria, Pakistan, Malaysia, and most of the states in the U.S. For a number of years, an early version of the lab manual was produced by the GPC Printshop in black and white, 3-hole punched. Some color pages were introduced in 2009, and students quickly demanded that the entire lab manual be made available in color. Beginning in 2010, the GPC Printshop produced the manual in full color with spiral-binding thanks to Barbara Lindsay Gatewood, Beverly Kelly, and others. I sincerely thank everyone who has contributed comments and suggestions to this lab manual, and everyone who has used it in their classes.

I wish to thank numerous colleagues who have contributed superb photographs to this edition, and museum staff that allowed photography or provided photographs, which have enhanced the laboratory manual considerably.

Thanks are also offered to Richard Hightower of The Stones and Bones Collection, and to Henry Crowley & Terry Lee of H & T Fossils, and others, for allowing me to photograph some of their amazing specimens.

Special thanks are extended to those at John Wiley & Sons, Inc. who have made this lab manual possible, including Ryan Flahive, Kathryn Hancox, Elizabeth Blomster, Joyce Poh, Julia Nollen, and many others.

And finally, thanks are extended to my family—my husband, Thomas J. Gore III, and daughter, Miranda J. Gore, who accompanied me to many of the localities photographed in this book. In addition, thanks are extended to Miranda for providing several of her photographs to this manual.

GUIDELINES FOR USING ACID TO IDENTIFY MINERALS

CAUTION!
BE VERY CAREFUL
if you use acid in the lab

The hydrochloric acid used in geology lab is typically dilute, but if handled improperly it can be hazardous. Hydrochloric acid can cause acid burns to the skin or eyes, and it will burn holes through clothing.

Whenever using acid, *always*:

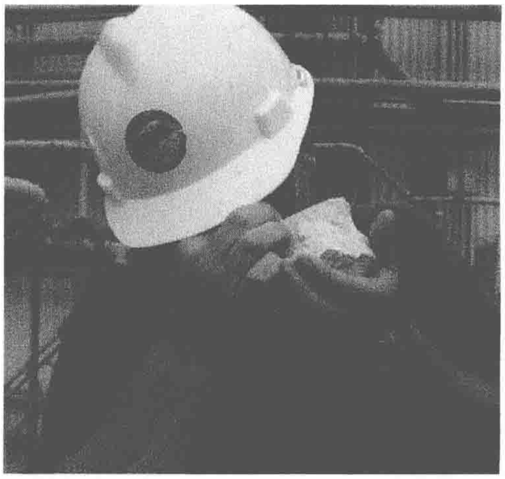
- **Follow directions carefully.**
- **Use a dropper bottle, and only apply one or two small drops to the sample.** Examine the sample to look for tiny gas bubbles. If the mineral is calcite, you will see them right away.
- Use care so you do not get the acid in your eyes or on the lab table, on your skin or clothes, or on any other person.
- Do not have any food or drink in the lab when acid is in use.
- Rinse specimens with tap water and blot with a paper towel after performing acid tests. Do not leave wet or acid-covered specimens on the lab tables, and do not put wet or acid-covered specimens back into the specimen trays.
- If you get acid on your hands, wash your hands immediately and notify your instructor.
- If you notice any adverse reactions after washing your hands thoroughly, get prompt medical attention.
- Do not rub your eyes after doing an acid test until after you have washed your hands.
- If acid get in your eyes, immediately flush your eyes with water for a minimum of 15 minutes using the emergency eyewash. Get prompt medical attention.
- If acid is spilled on other areas of the body, inform the instructor and use the safety shower, as appropriate. If the affected area is underneath clothing, remove the clothing. Get prompt medical attention.
- Report any acid spill immediately to the instructor.
- Close acid bottles securely, and return them to the acid storage area.

Follow your instructor's directions.

PROPER USE OF THE HAND LENS TO STUDY GEOLOGIC SAMPLES

1. Start with a 10× hand lens, and swing it open.
2. Curl your first finger and put it through the opening in the hand lens cover.
3. Hold the hand lens cover between your thumb and first finger.
4. Bring your hand up to your face so that your thumb is resting against your cheek, so that you can see through the hand lens.
5. Using your other hand, bring your geologic sample up toward your face, looking at it through the hand lens, until it is in focus, which will be about a half inch from your face.

Pamela Gore



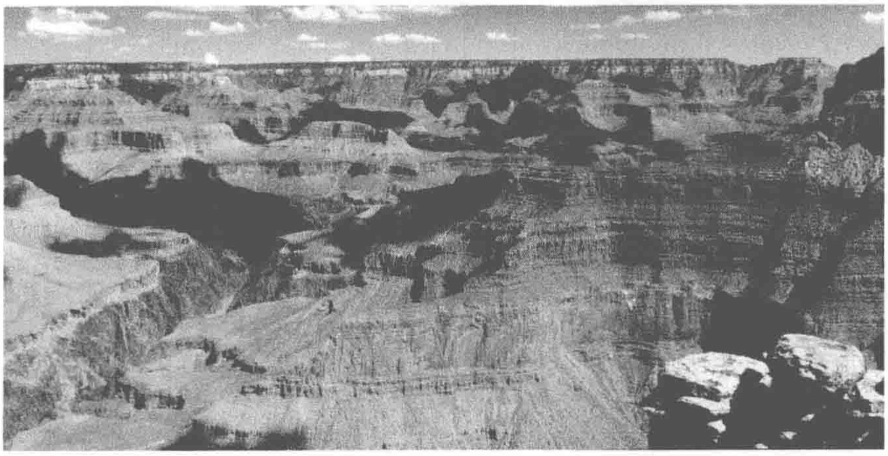
Pamela Gore

TABLE OF CONTENTS

LABORATORY 1

Relative Dating

This lab introduces the concept of **relative dating** of geologic sequences. Relative dating means determining which rock units are older and which are younger in a particular geologic setting. **Stratification** (layering or bedding) is the most obvious large-scale feature of sedimentary rocks (Figure 1.1). Bedding is readily seen in a view of the Grand Canyon or in almost any other sequence of sedimentary rocks. Each of the beds or **strata** is the result of a natural event in geologic history, such as a flood or storm. As time passes, many such events occur and the sediment piles up layer upon layer. In this way, thick sedimentary sequences are formed.



Grand Canyon National Park

Figure 1.1 Example of stratification or beds of sedimentary rock in the Grand Canyon, Arizona. View from Pima Point on the West Rim Drive, Grand Canyon National Park.

BASIC PRINCIPLES OF GEOLOGY

Steno's Laws

In a sedimentary sequence *the older beds are on the bottom and the younger beds are on the top*. You can visualize how this occurs if you imagine a stack of newspapers in the corner of a room. Every day you put another newspaper on the pile. After several weeks have passed, you have a considerable stack of newspapers, with the oldest ones on the bottom of the pile and the most recent ones on the top (Figure 1.2).

This fairly obvious but very important fact about layering—that older layers are on the bottom and younger ones are on top—was first noted in the 1600s by the Danish geologist Nicholas Steno. The **principle of superposition**, as it has come to be called, is the first of three principles now known as **Steno's laws** (Box 1.1). These three principles are based on observation and logic.

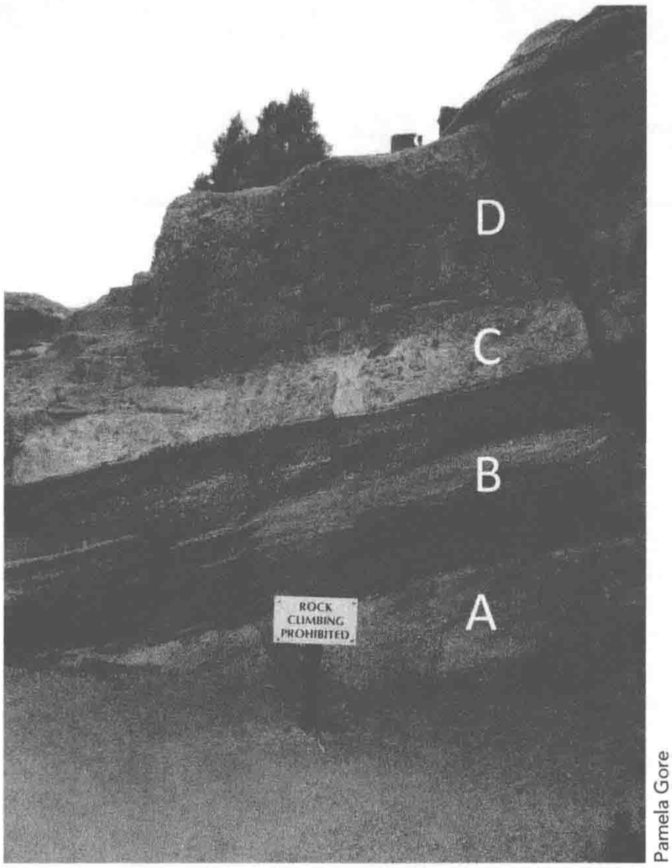


Figure 1.2 Vertical geologic section in the Fountain Formation. Layer A is the oldest, layer D is the youngest. Garden of the Gods, Colorado Springs, Colorado.

Steno's second law is the **principle of original horizontality**, which states that *sediments are deposited in flat, horizontal layers*. We can recognize this easily if we consider a sedimentary environment such as the sea floor or the bottom of a lake. Any storm or flood bringing sediment to these environments deposits it in a flat layer on the bottom because sedimentary particles settle under the influence of gravity. As a result, a flat, horizontal layer of sediment is deposited.

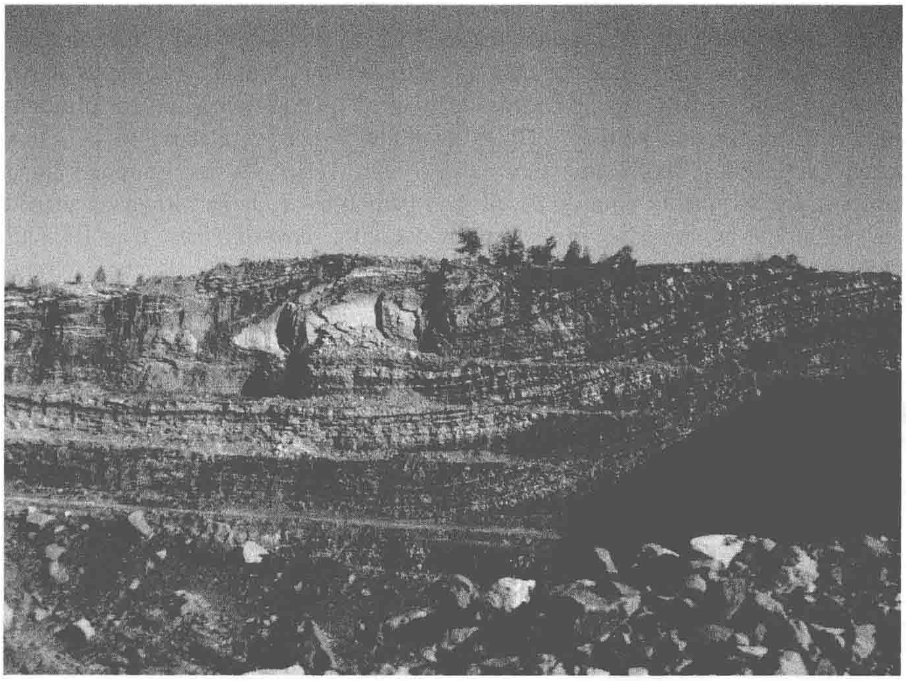
Steno's third law is the **principle of original lateral continuity**. If we consider again the sediment being deposited on the seafloor, *the sediment is not only deposited in a flat layer, it is a layer that extends for a considerable distance in all directions*. In other words, the layer is laterally continuous. Steno's laws are listed in Box 1.1.

Box 1.1 Steno's Laws

Principle of superposition
Principle of original horizontality
Principle of original lateral continuity

Of the three, the principle of superposition is most directly applicable to relative dating. We can examine any sequence of sedimentary strata and determine in a relative sense which beds are older and which beds are younger. All we need to know is whether the beds are right-side up or not.

This complication comes because tectonic forces can cause sedimentary sequences to be tilted, folded, faulted, and overturned (Figure 1.3). Although sediments are originally deposited in horizontal layers, they do not always remain horizontal. A trip to the mountains or a quick look through your textbook should convince you that many sedimentary sequences consist of layers or beds that dip at some angle to the horizontal, and in some cases, the beds are vertical or overturned.



Pamela Gore

Figure 1.3 Overturned fold in the Rockmart Slate, Rockmart, Georgia.

Lithologic Symbols

In diagrams, geologists use a standard set of **lithologic symbols** (from the Greek *lithos*, meaning "stone") to show rock types in diagrams such as stratigraphic sections or geologic cross sections. These symbols are used throughout this lab manual, and you will also find them used in your lecture textbook. Take a look through your textbook and see how many of the symbols in Table 1.1 you can identify in the geologic cross sections.

TABLE 1.1 LITHOLOGIC SYMBOLS

Symbol	Lithology	Symbol	Lithology
	Breccia		Limestone
	Conglomerate		Dolostone
	Sandstone		Volcanic rocks
	Siltstone		Plutonic rocks
	Shale		Plutonic rocks
	Coal		Metamorphic rocks

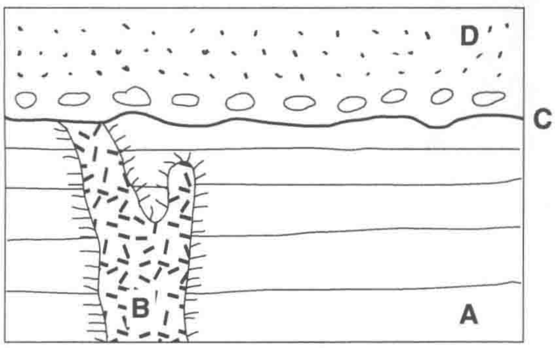
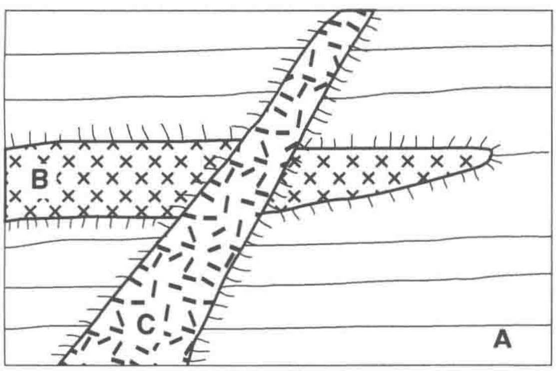
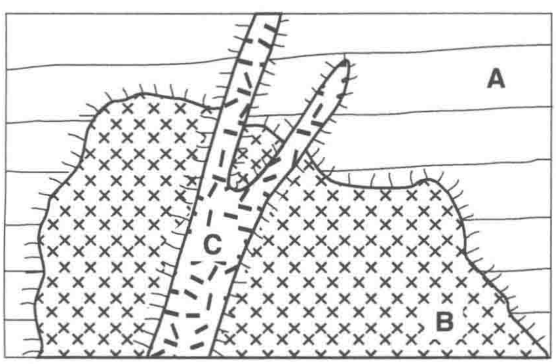
Other Basic Principles

In addition to Steno's laws, a number of other basic geologic principles can be used for relative dating.

The Principle of Intrusive Relationships

Where an igneous intrusion cuts across a sequence of sedimentary rock, the relative ages of these two units can be determined. *The sedimentary rocks are older than the igneous rock that intrudes them.* In other words, the sedimentary rocks had to be there first, so that the igneous rocks would have something to intrude. You could also say *the intrusion is younger than the rocks it cuts*. Examples of types of igneous intrusions (or **plutons**) are dikes, sills, stocks, and batholiths. **Dikes** are relatively narrow tabular intrusions that cut across the layers in the sedimentary rocks (Figure 1.4). **Sills** have intruded along the layers in the sedimentary rocks. Stocks and batholiths are larger, irregular shaped plutons. Batholiths are the larger of the two, by definition, covering more than 100 km^2 (or about 40 mi^2), whereas stocks are less than 100 km^2. The principle of intrusive relationships is illustrated in Table 1.2 using three types of igneous intrusions.

TABLE 1.2 PRINCIPLE OF INTRUSIVE RELATIONSHIPS

Illustration	Pluton type	Relative dating of layers
	Dike	Dike B is younger than sedimentary rock sequence A. Erosion surface C is younger than dike B. Sedimentary rock D is younger than erosion surface C.
	Dike and sill	Sill B is younger than sedimentary rock sequence A. Dike C is younger than sill B.
	Stock and dike	Stock B is younger than sedimentary rock sequence A. Dike C is the youngest.

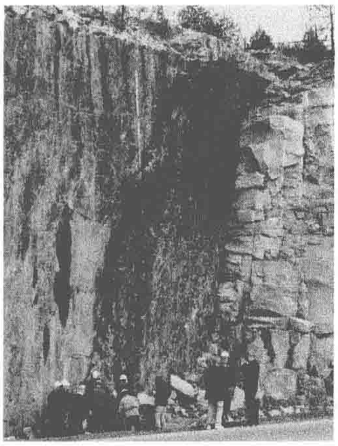


Figure 1.4 Jurassic-age diabase dike (*black*) cutting through the Norcross Gneiss. Vulcan Materials Quarry, Norcross, Georgia.

The Principle of Cross-Cutting Relationships

A **fault** is a crack in the rock along which movement has occurred (Table 1.3). Where a fault cuts across a sequence of sedimentary rock, the relative ages of the fault and the sedimentary sequence can be determined. *The fault is younger than the rocks it cuts.* The sedimentary rocks are older than the fault that cuts them, because they had to be there first before they could be faulted.

When observing a faulted sequence of sedimentary strata, always look to see how the beds on either side of the fault have been displaced. You might be able to locate a "key bed" that has been offset by the fault. If so, you will be able to determine the type of fault. Two types of faults are discussed in this lab: normal faults and reverse faults.

> In a **normal fault**, the hanging wall (HW), or the block of rock physically *above* the fault plane, moves down with respect to the foot wall (FW). Normal faults occur in response to tensional stress. Normal faults tend to occur at or near divergent tectonic plate boundaries (Figure 1.5).
>
> In a **reverse fault**, the hanging wall, or the block of rock physically above the fault plane, moves up with respect to the foot wall. Reverse faults occur in response to compressional stress. Reverse faults tend to occur at or near convergent tectonic plate boundaries. Thrust faults are a type of low-angle reverse fault (Figure 1.6).

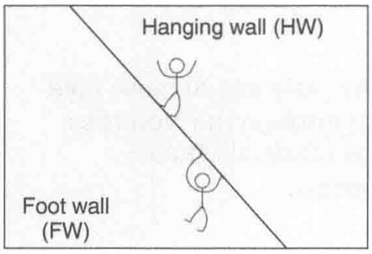
Principle of Components or Inclusions

In a sequence of sedimentary rocks, if there is a bed of gravel, *the clasts (or inclusions) of gravel are older than the bed in which they are contained.*

In many instances, the gravel directly overlies an irregular **erosion surface** (Figure 1.7). Sometimes it is obvious from the lithology that the clasts in the gravel bed are derived from the underlying partially eroded layer. If this is the situation, it is possible to place several layers and events in their proper relative order: (1) deposition of sedimentary rock sequence A; (2) erosion of sedimentary rock sequence A, producing an irregular erosional surface and rip-up clasts; (3) deposition of rip-up clasts of sedimentary rock A on top of the irregular erosional surface, producing a gravel bed. This gravel bed is sometimes called a **basal conglomerate** because it is at the base of the sedimentary sequence overlying the erosional surface.

A similar line of reasoning may be applied to igneous rocks if **xenoliths** are present (Figure 1.8). You may remember from physical geology that a xenolith (which literally means "foreign rock") is a piece of surrounding rock (sometimes called "country rock") which becomes caught up in an intrusion. As magma moves upward, forcing itself through cracks in the surrounding rock, sometimes pieces of these surrounding rocks break off or become dislodged and incorporated into the magma without melting. These pieces of rock are called *xenoliths*, and they move along with the magma. According to the principle of components or inclusions, *xenoliths are older than the igneous rock that contains them.*

TABLE 1.3 FAULT TERMINOLOGY

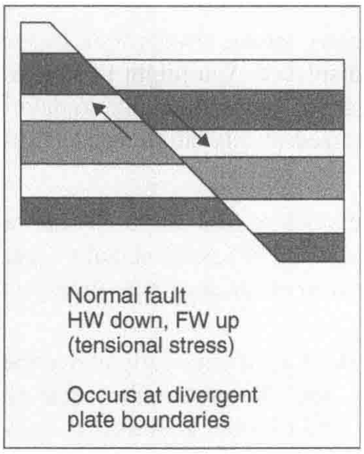


Hanging wall (HW) = the block of rock physically *above* the fault plane.

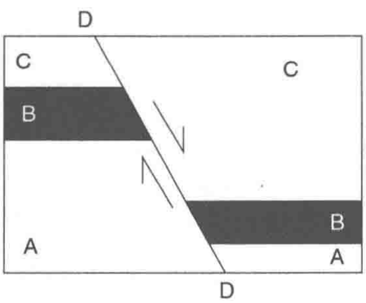
Foot wall (FW) = the block of rock physically *below* the fault plane.

Notice the little blue figures. Their hands are on the hanging wall and their feet are on the foot wall.

Normal Faults

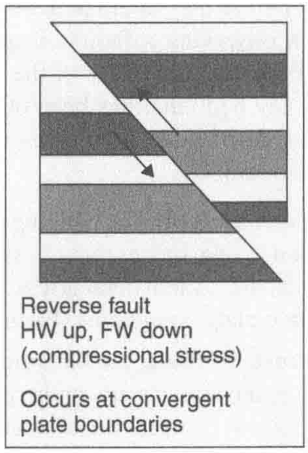


In a normal fault, the HW moves down, and the FW moves up. Normal faults occur at divergent plate boundaries under tensional stress.

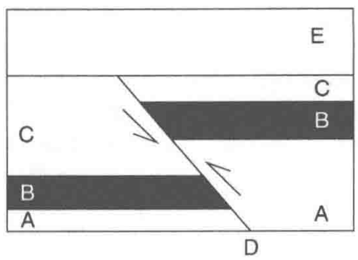


Unit A is the oldest, followed by B and C. Fault D is the youngest.

Reverse Faults



In a reverse fault, the HW moves up, and the FW moves down. Reverse faults occur at convergent plate boundaries under compressional stress.



Unit A is the oldest, followed by B and C. Fault D is younger than C but older than unit E.