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SCIENCE

STUDENT BOOK

9th Grade | Unit 4

Alpha Omega
PUBLICATIONS

SCIENCE 904

Historical Geology

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Author:
Lee H. Dunning, M.S.T., M.S.Ed.

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804 N. 2nd Ave. E.
Rock Rapids, IA 51246-1759

Historical Geology

Introduction

The responsibility of historical geology is interpreting the changes that have occurred in the earth's crust. Evidence for change comes in the form of folds, faults, and fossils. The evidence is plentiful and unmistakable. The time frame during which the changes took place is not so unmistakable, however. The literature of geology—texts and periodicals—assign an age of 4.6 billion years—give or take a few hundred million years. The Bible describes the Creation of the earth and all things on it as requiring six days, with about six thousand years having passed from the Creation to the present. The Bible is God's truth revealed. It is not a book of science, but it is scientifically accurate. The ages of the rocks may be difficult to determine, but the Rock of Ages stands ready to make Himself known to all who will come to God by personal faith in Him.

The message of the Gospel is eternal life by faith in our Savior. John wrote (John 3:36) "He that believeth on the Son hath everlasting life…" When the jailer in Acts 16:30 asked Paul and Silas what he had to do to be saved, he was told to "…Believe on the Lord Jesus Christ, and thou shalt be saved…." Our path to glory is well-marked, and our Creator-Father will not deceive us (Psalm 23). If we are presently unable to reconcile our interpretations of God's Word and God's world, the problem lies neither in the Word nor the world, but in the interpretation.

Objectives

Read these objectives. The objectives tell you what you will be able to do when you have successfully completed this LIFEPAC. When you have finished this LIFEPAC, you should be able to:

1. Relate the early attempts at deciphering earth history.
2. Explain the difference between experimental and observational science.
3. Explain the importance of sedimentary rocks in interpreting earth history.
4. Name several sedimentary rocks on the basis of their components.
5. Describe the transportation, deposition, and lithification of granitic minerals.
6. Apply the ordered arrangement of rock unit names.
7. Describe several ways by which organisms are preserved as fossils.
8. List several divisions of the study of fossils.
9. Cite evidence for uplift and deformation of the earth's crust.
10. Explain the economic importance of deciphering the history of an area.
11. Explain the difference between relative time and absolute time, and to cite examples of each.
12. Interpret rock sequences.
13. Describe several techniques used to date the earth.

Survey the LIFEPAC. Ask yourself some questions about this study and write your questions here.

1. AN OBSERVATIONAL SCIENCE

Astronomy and geology are classified as *observational sciences*. Physics, chemistry, and biology are *experimental* sciences: the chemist can test and retest his hypotheses in a laboratory. However, neither the geologist nor the astronomer can perform his research in the laboratory.

The geologist must depend upon evidence—the testimony of silent witnesses to the events of the past. For the most part, the silent witnesses are sedimentary rocks—the structures and fossils found in the crust of the earth.

SECTION OBJECTIVES

Review these objectives. When you have completed this section, you should be able to:

1. Relate the early attempts at deciphering earth history.
2. Explain the difference between experimental and observational science.
3. Explain the importance of sedimentary rocks in interpreting earth history.
4. Name several sedimentary rocks on the basis of their components.
5. Describe the transportation, deposition, and lithification of granitic minerals.
6. Apply the ordered arrangement of rock unit names.
7. Describe several ways by which organisms are preserved as fossils.
8. List several divisions of the study of fossils.
9. Cite evidence for uplift and deformation of the earth's crust.
10. Explain the economic importance of deciphering the history of an area.

VOCABULARY

Study these words to enhance your learning success in this section.

algal (al´ gul). Having to do with algae.

cementation (sē´ mun tā´ shun). Precipitation of a binding material around grains in rocks.

clastic (klas´ tik). Composed of detritus, which are small fragments such as gravel, sand, or silt.

compaction (kum pak´ shun). Decrease in the volume of sediments that results from continued deposition above them.

coprolite (kop´ ru līt). The fossilized undigestible residue that has passed through the alimentary canal of some animal.

debris (du brē´). A mass of fragments worn away from rock; detritus.

epeirogenic (i pī´ rō jen´ ik). Uplift and subsidence of large land masses without significant deformation.

gastroliths (gas´ tru liths). Highly polished, well-rounded pebbles believed to have been stomach stones of dinosaurs.

invertebrate (in vėr´ tu brit). Without a backbone.

lithification (lith´ u fu kā´ shun). The process by which rocks are formed from sediment.

marine (mu rēn´). Found in the sea; produced by the sea.

micropaleontology (mī´ krō pā´ lē on tol´ u jē). Paleontology of minute fossils.

orogenic (ôr´ u jen´ ik). Formation of mountain ranges by folds, faults, upthrusts, and overthrusts.

paleobotany (pā´ lē ō bot´ u nē). The study of plants through the study of fossils.

paleontology (pā´ lē on tol u jē). The science of plant and animal fossils.

petrifaction (pet´ ru fak´ shun). A petrifying; conversion of organic matter into stone or a substance of stony hardness.

petrified (pet´ ru fīd). Turned into stone.

recrystallization (rē kris´ tu lī zā´ shun). Formation of mineral grains in a rock while in the solid state.

turbidity current (tėr bid´ u tē kėr´ unt). A relatively dense current that moves along the bottom slope of a body of standing water.

vertebrate (vėr´ tu brit). Having a backbone.

Note: *All vocabulary words in this LIFEPAC appear in* **boldface** *print the first time they are used. If you are not sure of the meaning when you are reading, study the definitions given.*

Pronunciation Key: h**a**t, **ā**ge, c**ã**re, f**ä**r; l**e**t, **ē**qual, t**ė**rm; **i**t, **ī**ce; h**o**t, **ō**pen, **ô**rder; **oi**l; **ou**t; c**u**p, p**u̇**t, r**ü**le; **ch**ild; lo**ng**; **th**in; /ŦH/ for **th**en; /zh/ for mea**s**ure; /u/ represents /a/ in **a**bout, /e/ in tak**e**n, /i/ in penc**i**l, /o/ in lem**o**n, and /u/ in circ**u**s.

THE SCIENCE

Historical geology dates back 2500 years, but did not emerge as a science until just 200 years ago. Its graduation to the status of science came with the scientific method of inquiry: observation and experimentation as a means of testing hypotheses.

The first application of observation to historical geology came in a classic argument between the Neptunists and the Plutonists—the origin of rocks.

Early observations. The Greek historian Herodotus (484-425 B.C.) observed that soil transported by the Nile was changing the coastline of Egypt where it entered the Mediterranean Sea. The Italian engineer, Leonardo da Vinci (1452-1519), noted fossil beds in rock being used on roads and canals. The Dane, Niels Stensen (1638-1687),—better known by his Latin name, Steno, wrote a volume in which he displayed an understanding of geologic principles. Among those principles was an appreciation that rocks now folded and faulted were originally horizontal.

Neptunists versus Plutonists. The origin of rocks became a topic of controversy between two schools of geologists near the end of the 1700s. The *Neptunists* held that *all* crustal rock was precipitated from an ocean that covered the entire earth before the beginning of life. The *Plutonists*, on the other hand, believed that what we today call igneous rock has a different origin. The Plutonists believed that these rocks arrived at the surface of the earth as molten rock, called lava. Geological field observations, however, solved the controversy in favor of the Plutonists. Basalt, hardened lava, was traced to the volcanic vent from which it erupted.

Experimental versus observational. In 1782, the great French chemist, Antoine Lavoisier, investigated several quarries near Paris. These quarries provided clay for pottery and porcelain. Lavoisier observed that all the quarries exposed the same sequence—the same vertical order of sedimentary rocks.

Two other Frenchmen, Georges Cuvier and Alexandre Brongniart, in 1810 and 1822, published maps of rock types found near Paris. They studied the fossils in sedimentary layers and discovered that each layer contained a different group of fossils.

Cuvier and Brongniart concluded that a sedimentary layer could be identified by the fossils it contains. In 1815 William Smith published a map of the rocks of England. Smith reached the same conclusion about fossil content in the rocks of England, that sedimentary layers could be recognized by their fossil content.

Last century, several attempts were made to measure the age of the earth. The hypotheses were later proved incorrect, and therefore, the conclusions were incorrect. The attempts were based on the assumptions that geological activities now occurring on the earth's surface have occurred *at the same rate* throughout time. A second assumption held that what is observed today is the result of only the activity being investigated. However, several other factors were involved in addition to those being investigated.

The conflict between Neptunists and Plutonists gives an example of the part that field observation plays in uncovering the secrets of geology. Most geologic processes cannot be duplicated in the laboratory because of limited time and materials. For instance, a chemist can react two substances many times to confirm a hypothesis. He can weigh and measure each substance before and after the experiment. A geologist, however, cannot reproduce a flood or an earthquake or a volcanic eruption in the laboratory, for obvious reasons. In this respect, geology is unlike physics, chemistry, or biology, which are "laboratory sciences." In geology, observation replaces experimentation as the investigative tool. Instead of reproducibility the geologist relies on clues he finds in the rocks and the landscape to provide the basis for his conclusions. A good geologist is, above all, a good observer.

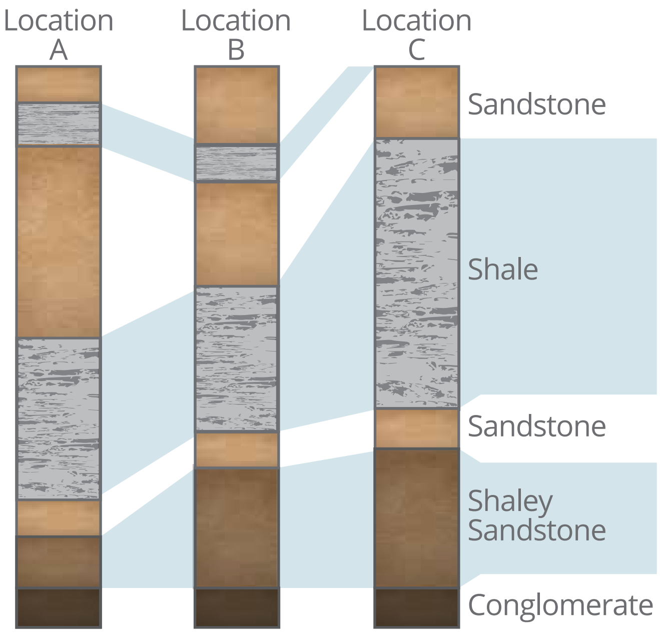

Figure 1 | Sedimentary Sequences

Write true or false.

1.1 ____________ Sedimentary rock is deposited in horizontal layers.

1.2 ____________ The geologist depends primarily on experimentation.

Write the letter for the correct choice on each line.

1.3 Steno observed that ________ .
a. basalt came from volcanoes
b. sediment is deposited in horizontal layers
c. fossils are remains of plants and animals
d. sediment becomes lithified

1.4 Herodotus lived around the year ________ .
a. 2500 B.C. b. 500 B.C. c. A.D. 500 d. A.D. 1200

Complete these sentences.

1.5 The group of geologists who thought *all* crustal rock was precipitated from an ocean were called ____ .

1.6 The geologists who understood the origin of crustal igneous rock were called ____ .

1.7 Geological investigations in the late 1700s and early 1800s were carried on in the nation of ____ .

1.8 If the hypothesis of an investigation is incorrect, the ________________________________ will also be incorrect.

Answer these questions.

1.9 What observation proved the Plutonists to be correct? ____
____
____
____

1.10 What two limitations does a geologist have on his ability to experiment?
a. ______________________________ and b. ______________________________ .

1.11 Why is geology an observational science and not an experimental science?

____

____

____

____

____

____

Complete this activity.

1.12 Describe the conclusions of the work of Cuvier, Brongniart, and Smith.

____

____

____

Complete this activity.

1.13 The three columns represent the rock sequences in three quarries. Letters stand for different rock types. (The top rock type d is eroded away at each quarry, and the bottom of rock type a cannot be located.) Draw straight lines to represent the contacts between the rock types. The example given represents the contact between rock type c and rock type d.

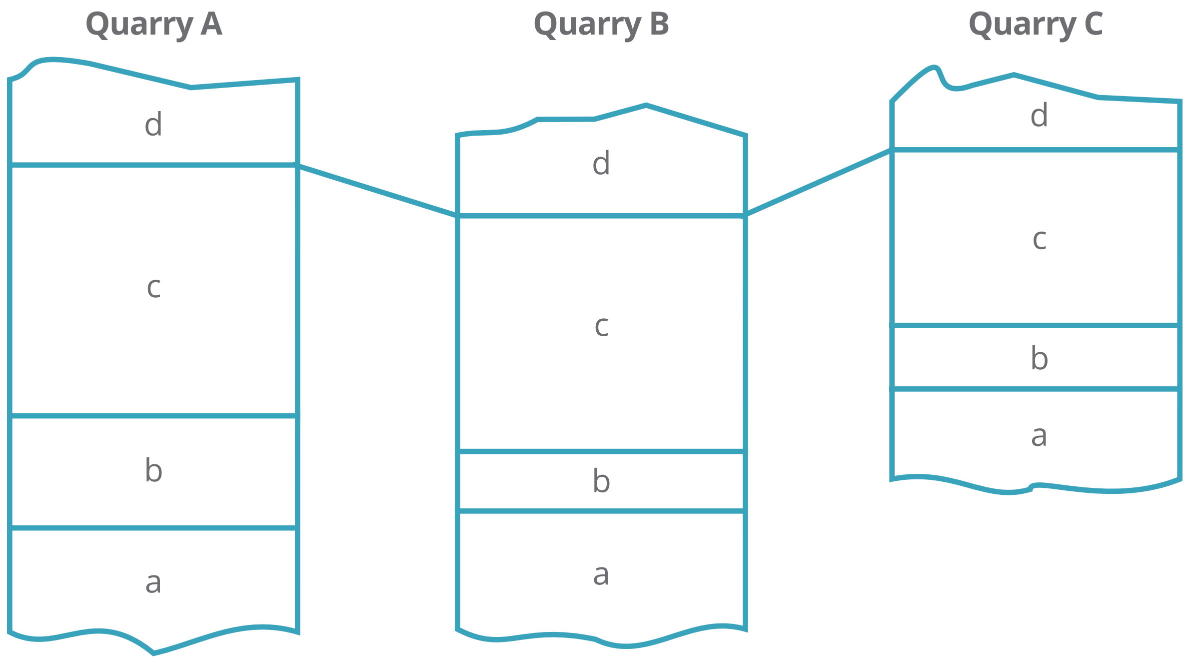

Figure 2 | Rock Sequences

Complete this assignment.

1.14 Select *two* of the following topics. Conduct library research and write a five-page report plus a bibliography on each. Do not use words you do not understand. Submit the reports to your teacher for grading on content and structure.

a. Gondwanaland (use sources written after 1968).
b. Conodonts
c. Tree rings
d. James Hutton
e. Continental glaciation
f. Radiocarbon dating
g. The Colorado Plateau
h. Coral reefs
i. Immanuel Velikovsky
j. Catastrophism and Uniformitarianism
k . Magnetic reversals
l. Cephalopods
m. Leonard Wooley
n. Wolly mammoth
o. Dinosaurs
p. Tar pits
q. Charles Lyell

TEACHER CHECK ____________ initials ____________ date

SEDIMENTARY ROCKS

Of the three categories of rock—igneous, sedimentary, and metamorphic—sedimentary rocks are of greatest importance in historical geology. For several reasons, they contain clues for which the geologist looks to interpret earth history. Before studying the clues themselves, we shall examine the rocks, their information, and their organization.

Source of information. Sedimentary rocks are of interest in historical geology for several reasons.

First, sedimentary rocks form at the earth's surface. They form at temperatures and pressures that are common to life. Igneous and metamorphic rocks, on the other hand, form at high temperature and frequently at high pressure. Because sedimentary rocks are deposited under surface conditions, they represent those conditions with which life is comfortable: the environment of the earth's surface. Historical geology, for the most part, is the history of the earth's surface.

Second, sedimentary rocks are the burial ground for former life. Sedimentary rocks preserve the remains of creatures that have lived in the surface environments. Life cannot exist very far below or above the earth's surface. In terms of the scale of Figure 3, the earth's

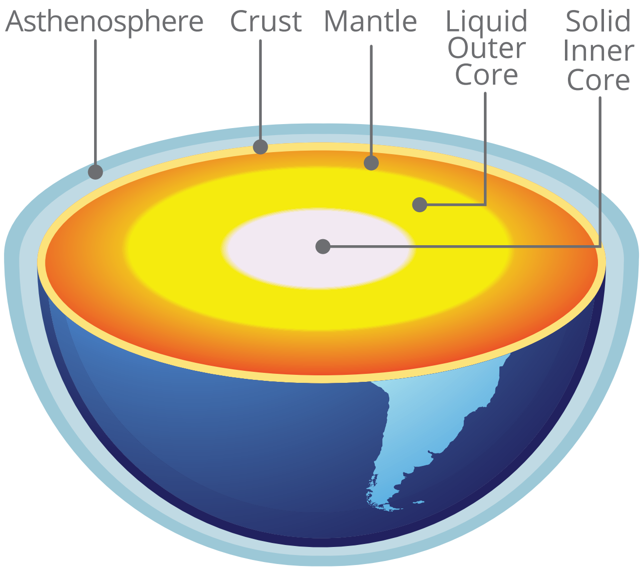

Figure 3 | The Thin Crust

surface is a small fraction of a millimeter. When plants and animals die, they accumulate on the surface where they decompose to some degree. Historical geology is concerned with the creatures that are preserved—fossilized—as a record of life. The study of fossils will be developed later in this section.

Third, sedimentary rocks preserve a record not only of life, but of environments. Sand that is deposited by wind has characteristics somewhat different from sand deposited by waves. A sand dune leaves a "thumbprint" in the rock that is different from that of a sand bar, a glacial till, or river sand. The geologist's trained eye can recognize features that tell him the environment in which the rock was deposited. A limestone could not have been deposited on a mountaintop, even though it may now be found there. Limestones are not deposited in mountains, but beneath the sea. The limestone, then, is evidence that something happened to raise rock once beneath the sea to the height of a mountaintop.

Fourth, sedimentary rocks represent the passage of time. With a few notable exceptions, sediment at the bottom of a layer was deposited before sediment at the top. The rock between the bottom and the top is a relatively complete record of the events that took place in that place during that time interval. One exception to this generalization concerns the members of a graded bed produced by a **turbidity current**. A turbidity current is a fast-moving underwater stream of silt or mud, usually along the bottom of a deep body of water such as a reservoir or the ocean. Such a graded bed is deposited in a matter of hours after the turbidity current slows down. Other exceptions are **debris** from an avalanche or a mudflow, which may be laid down in a matter of minutes.

In a way, the *lack* of sedimentary rocks also represents the passage of time. If limestone overlies a sand dune, the paper-thin plane between them, called a contact, represents the time

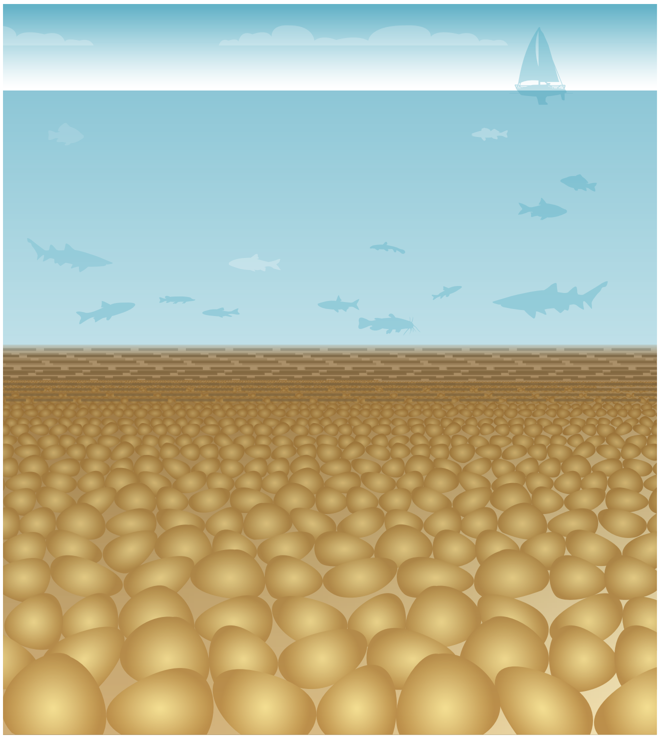

Figure 4 | Graded Bed

during which the desert became submerged and became an underwater environment. Interruptions in the depositional record will be developed in Section II.

A common assumption says that the upper surface of a rock layer is a *time plane*. That is, the grains of sediment on the plane of contact that separates one layer from another were all deposited at the same time. That assumption must be tested for every layer investigated in the field. It will, however, be accepted as a good generality.

Formation. Sedimentary rocks may be thought of as a second-generation rock—an accumulation of chips off the old block. The "old block," in the case of **marine** sandstone, could be granite in the hills from which flow the streams that enter the ocean.

Let us use the example of a granite mountain range being weathered. The granite debris is transported by streams toward the ocean. On the way to the ocean, the sediment is broken into smaller pieces, generally into the individual minerals found in granite: quartz, feldspar, and mica. The quartz is not affected by chemical weathering. It arrives at the ocean as small, somewhat rounded, grains of “sand.” Feldspar and mica are affected by chemical weathering. They undergo chemical changes that convert the flakes and grains of mica and feldspar to *clay minerals*. The degree of the chemical change is a clue to the length of time the mica and feldspar have traveled. In general, the more clay, the longer the travel time.

Usually the *transporting medium*, in this case a river, *winnows* the sediment, separating one part of it from another. Sand and clay are not usually deposited together. The environment of deposition that is friendly to one kind of sediment may not be friendly to another kind.

At the end of the journey, particles of sand and clay, the product of eroded granite, are deposited. Deposited sediment is soon covered by later-arriving sediment. When the depth of the overlying sediment is sufficient, three processes convert the sediment back into rock. The three processes are **compaction**, **recrystallization**, and **cementation**. The weight of overlying sediment presses the grains of sediment together, squeezing out most of the seawater trapped between the grains, and packing the grains into a smaller volume. Compaction increases the density of the sediment, bringing the grains together under pressure. It also increases the force of one grain on another. This increased contact under increased pressure causes the grains to do an interesting thing: the grains actually *grow* together. This growth has the effect of strengthening the rock and is called *recrystallization.* The points of contact become tiny welds. Seawater has an abundance of tiny welds. Seawater has an abundance of dissolved mineral salts like sodium chloride (NaCl). Under the new conditions of burial, the salts come out of solution and precipitate on sand-grain surfaces and develop their own structure. This crystal growth fills the spaces between sand grains and cements them together. The third process of converting sediment to rock, then, is *cementation.* The result of compaction, recrystallization, and cementation is **lithification**—the making of rock.

Names and organization. Sedimentary rocks have been named so they can be studied. The rock name is commonly taken from the substance that makes up the rock: *sandstone* is made of sand-size particles; *siltstone* is made of

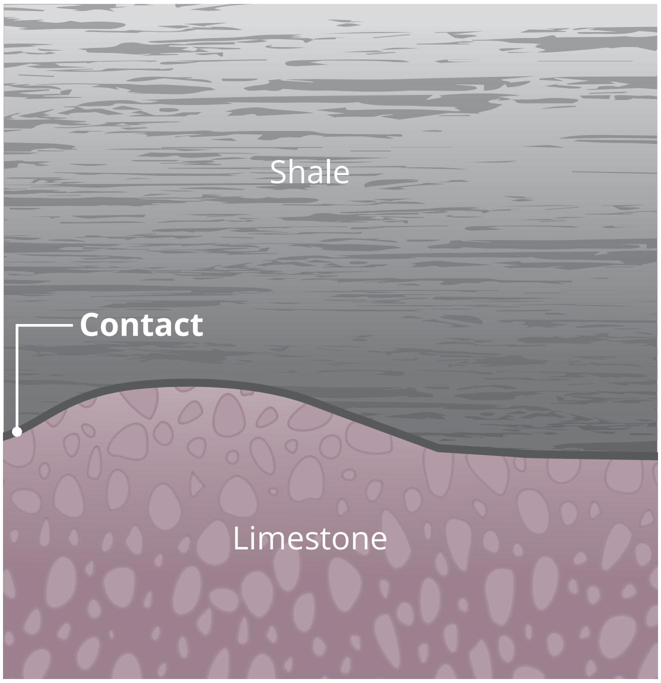

Figure 5 | Formation Contact

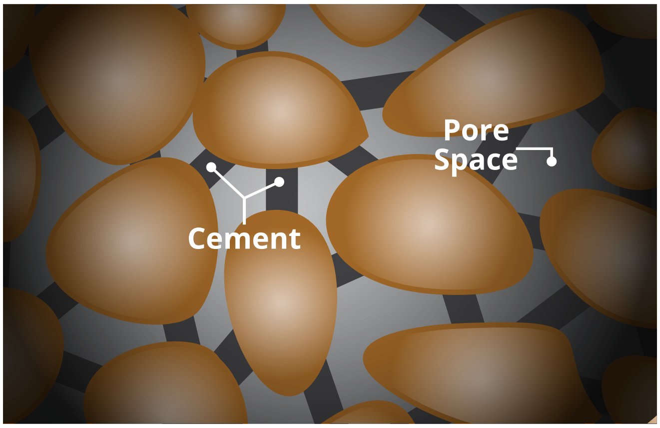

Figure 6 | Cement Between Sand Grains

silt-size particles; *mudstone* and *claystone* follow the same rule.

Gravel, sand, and mud are **clastic** sediments; they are composed of particles that result from the wearing away of pre-existing rock. Another group of sediments result from life processes of water-living organisms. Clams, snails, sponges, sea urchins, and even algae extract dissolved salts from seawater to construct their life-support structures. When the organisms die, their structures collect in great abundance on the sea floor and eventually become lithified as *limestone.* In recent years investigations have ruled out the hypothesis of direct chemical precipitation of limestone. Calcium carbonate must pass through the life cycle of an animal or plant before it becomes the component of a rock.

The first step in identifying a sedimentary rock, then, is classifying the component grains into one of several categories on a size scale. The categories and their limiting diameters are given in Figure 7.

Few sediments are of a uniform grain size: a sand commonly contains some silt or some pebbles. The *lithified* result in these two examples is a *silty sandstone* or a *pebbly sandstone.*

Notice that *sand* is defined on the basis of *size* alone. Grains of any mineral that are larger than 0.0625 mm and smaller than 2.0 mm are sand grains. Residents of the Atlantic and Pacific coasts think of sand in terms of quartz grains, and for good reason. Beaches along those coasts are supplied with sediment by rivers that flow from the Appalachian Mountains on the east or the Sierra Nevada and Coast Ranges on the west. These mountains have high quartz content. Residents of the Florida Gulf Coast, however, observe seashell fragments. Hawaiians, on the other hand, see black basaltic sand derived from the volcanic rock of the islands.

The name of the rock is usually derived from the sediment grain size, but how is one sandstone distinguished from any other sandstone? How can the geologist communicate

Size	Sediment		Sedimentary Rock	
	gravel	boulder	conglomerate	clastic
		cobble		
		pebble		
		granule		
2.0mm	sand	coarse sand	sandstone	
		medium sand		
		fine sand		
0.0625mm	mud	silt	siltstone mudstone claystone	
		clay		
	seashells		limestone	nonclastic
	sponge spines			
	algal structure			
	coral fragments			

Figure 7 | Grain Size Classification

the idea that two pieces of sandstone are of different age, from two separate geographic locations, and perhaps even from different environments?

The first step in answering these questions is to refer to an ordered arrangement of names used in geology. An example of an ordered arrangement is found in the Bible: Testament, book, chapter, verse.

A book contains chapters, and a chapter is composed of verses. Several related books constitute a Testament.

The fundamental sedimentary rock unit is called a *formation.* A formation is identified on the basis of how and when it formed. For instance, the Tapeats sandstone of northern Arizona was deposited in a single environment, along a seashore and was deposited continuously without any significant interruption. Variations within the Tapeats sandstone formation are called *members,* and divisions of members are beds. The Tapeats sandstone is one of three formations deposited under similar conditions. Therefore, the Tapeats sandstone, the Bright Angel shale, and the Mauv limestone are referred to as the *Tonto Group.* By analogy,

Testament ↔ Group

Book ↔ Formation

Chapter ↔ Member

Verse ↔ Bed

Group, formation, member, bed—now you have it in your head.

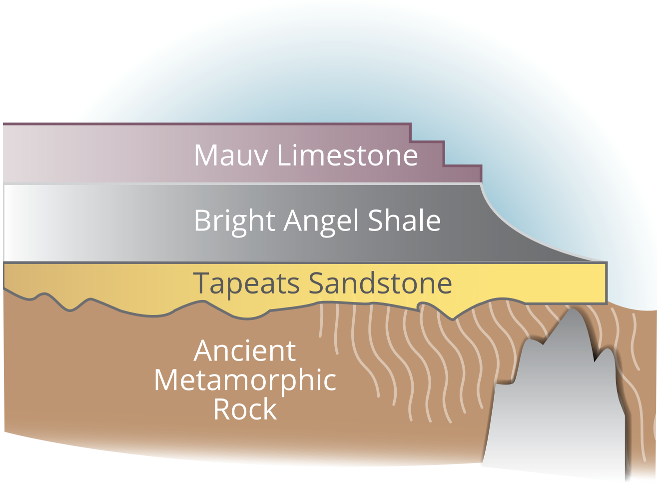

Figure 8 | The Tonto Group

If a formation is composed of two or more rock types, it is usually not given a rock-type name. An example is the Chinle *formation,* which is composed of sandstones and siltstones.

Take a field trip.

Find out where sedimentary rock can be found in your area. Ask your teacher or another science teacher, or contact the department of geology at a nearby college. (Ask if you can attend a field trip sponsored by the college.)

Take with you a felt-tip pen, a dozen plastic sandwich bags with ties, a pen or pencil, two grocery bags made into one, a clipboard, and about twenty 3" x 5" cards to record the following information about the sedimentary rocks you will collect (an example is given):

I.D. No. 9

Location: *N. side of road, 3 mi. W. of town*

Thickness of bed: *approx. 10 m.*

Altitude: *dipping @ 30° to the north*

Sediment type: *sand with some pebbles*

Rock name: *pebbly sandstone*

Rock above: *sandstone*

Rock below: *conglomerate*

1. Horizontal or tilted.

1.15 Match each rock to a card with an identification number. Write the number on the rock with your felt-tip pen. Use the sandwich bags for fossils and small or crumbly rocks.

Secure permission from your parents for the trip.

Set up a display of your samples in the classroom, arranged as they were in the field, and labeled with the cards.

Parent Permission ________ initials ________ date

TEACHER CHECK ________ initials ________ date

Write true or false.

1.16 __________ The top of a sedimentary layer was deposited before the bottom.

1.17 __________ A graded bed deposited in a matter of hours is called a turbidity current.

1.18 __________ Highly weathered feldspars and micas mean that the granite source is a considerable distance away.

1.19 __________ Quartz is not affected by chemical weathering.

1.20 __________ Limestone precipitates from seawater as the result of a chemical reaction.

Write the letter for the correct choice on the line.

1.21 Limestones are deposited ________ .
a. on mountains b. beneath the sea c. in river beds d. in sand bars

1.22 Sand along both the Atlantic and the Pacific coasts is chiefly ________ .
a. basalt b. seashells c. granite d. quartz

1.23 One process not involved in lithification is ________ .
a. cementation b. recrystallization c. transportation d. compaction

1.24 Gravel is sediment larger than ________ .
a. 2 inches b. 2 mm c. 0.0625 mm d. 0.625 mm

1.25 The name of a sedimentary rock is usually based on ________ .
a. its history b. its degree of lithification
c. its grain size d. its thickness

Complete these sentences.

1.26 Both igneous and metamorphic rocks form at ______________ temperatures and pressures.

1.27 Historical geology is the history of the earth's ____

____ .

1.28 Traces of formerly living organisms, found in sedimentary rocks, are called

____________________________________ .

1.29 An igneous rock that contains quartz, feldspar, and mica is _______________________________ .

1.30 The product of chemical weathering of granite is ____ .

1.31 The total process that changes sediment into rock is called _______________________________ .

1.32 Gravel, sand, and mud are _______________________________ sediments.

1.33 The fundamental sedimentary rock unit is the ____ .

1.34 A variation of the fundamental rock unit is a ____ .

1.35 Several related fundamental rock units is a ____ .

Answer these questions.

1.36 What is the relationship between fossils and sedimentary rock?

____

____

____

1.37 What is the significance of limestone on mountaintops?

____

____

____

____

____

____

Complete these activities.

1.38 Explain the meaning of the sentence, "The lack of sedimentary rocks represents the passage of time." ____

____

____

____

____

1.39 Explain why sedimentary rocks are "second-generation" rocks. ______________________

____

____

____

____

1.40 Name three effects that a stream has on the sediment it carries.

a. ____

b. ____

c. ____

1.41 Explain the difference between clastic rocks and limestone.

____

____

____

1.42 Describe the three processes involved in lithification.

a. compaction ____

____

____

b. recrystallization ____

____

____

c. cementation ____

____

____

Complete the table.

1.43

Sediment		**Sedimentary Rock**
seashells	→	d.
mud	→	e.
gravel	→	f.
a.	→	siltstone
b.	→	limestone
sand	→	g.
algal structures	→	h.
c.	→	comglomerate

Complete these activities.

1.44 Identify the “sediment” in each box in terms of its size.

a. ____________________ b. ____________________ c. ____________________

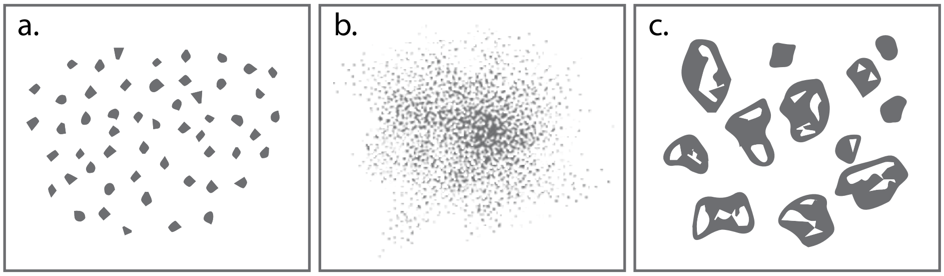

Figure 9 | Sediment Samples

1.45 Arrange bed, group, member, and formation in the correct ordered arrangement of terms.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

FOSSILS

Fossils are the evidence of organisms, preserved in rock in the earth's crust. Fossils occur individually and in communities. Fossils may be found in the environment of the organism's *life,* but more frequently they represent the environment of its *death*. Fossils may be found at the location of death, or the organism may have been carried many kilometers to the site where its fossil is found. Fossils are important to science and are interesting to study.

Formation of fossils. For the purpose of learning how fossils form, a review of why they *don't* form will be helpful. When buried, organic debris or organisms will decompose, or break down, and release nutrients into the soil, nutrients that are taken up by the flowers in the garden. In short, organic debris and organisms decompose when exposed to oxygen, bacteria, and scavengers.

When an organism dies, the last part to decompose is its skeletal structure—the hard parts: bones, teeth, shells, spines, or plates. Even these structures will eventually break down, under normal circumstances.

How, then, are some organisms preserved to become fossils? Generally, *fossilization* requires the organism to have hard parts, and to be buried quickly. Fleshy parts of an organism decay first. Few fossils contain fleshy parts or even traces of fleshy parts. The most common fossils are seashells. Seashells are hard parts. Their inhabitants live in an environment that is constantly being covered with sediment. Organisms that die in the oceans are buried quickly. They are hidden from scavengers and are out of reach of abundant oxygen.

When the organism is buried, the tissue and even the shell are replaced with salts that are always found in seawater. The shell becomes **petrified**, or turned to rock.

Organisms buried in mud are more likely to be preserved than those buried in sand. Sand allows oxygen-bearing water to flow through. The oxygen speeds decay. Mud does not permit flow and therefore slows decay by keeping oxygen away from buried organisms.

Organisms are fossilized in several different ways. **Petrifaction**, mentioned earlier, occurs when the shell is replaced molecule by molecule with dissolved salts, usually *silica* (SiO^2) or *calcite* ($CaCO^3$). Occasionally the replacing material is pyrite ("fool's gold"), fluorite, gypsum, galena (lead ore), sulfur, or one of several other possibilities. Sometimes fossil vegetation becomes the nucleus for precipitating silver or uranium, as is the case in the western United States.

A second method of fossilization is the total removal of the shell. Only the hollow space, or *mold,* remains. If the hollow space is later filled with minerals, a *cast* is formed.

If the liquid and gaseous makeup of an organism is squeezed out under high pressure, a thin film of carbon remains in the shape of the organism. This third method of fossilization is called *distillation.*

Least common fossils are those that have been *frozen* or *mummified.* Several whole woolly mammoths have been found frozen in the Siberian ice. Woolly rhinoceroses, mammoths, sabre-toothed cats, and other large mammals have been preserved in oil seeps in the western United States and in Poland. Human bodies have been found in peat bogs formed from ancient swamps in Denmark and Holland. Conditions for preservation are so good in Peat Bogs and oil seeps that skin, hair, and even internal organs have been preserved.

In addition to the remains of organisms, tracks, trails, and burrows are also fossils because they are "evidence of organisms, preserved in rock." Fossils that do not reveal the body form are called *trace fossils*. Even gizzard stones **(gastroliths)** and droppings **(coprolites)** have been identified as fossils.

Science of fossils. **Paleontology** is the study of fossils. It is divided into four subsciences: **invertebrate** paleontology, **vertebrate** paleontology, **paleobotany**, and **micropaleontology**.

Invertebrate paleontology studies organisms that lack vertebral columns or backbones. Invertebrates include amoebas and sponges, sea urchins and jellyfish, barnacles and clams, octopi and lobsters, insects and spiders.

Vertebrate paleontology studies the classes of animals that have internal skeletons and well-developed nervous systems: fish, amphibians, reptiles, birds, and mammals.

Paleobotany is the study of plant fossils. Many specimens of plant fossils have been collected from coal fields. A branch of paleobotany is the study of fossil pollen and spores. Flowers produce thousands of pollen grains. Thus, even when a plant has not been preserved, its pollen is likely to be present.

Micropaleontology is the study of fossils visible only with a microscope. Marine protozoans (one-celled animals) with shells aid petroleum geologists in their search for oil.

Answer these questions.

1.46 What two conditions are usually required for an organism to be fossilized?

a. ______________________________

b. ______________________________

1.47 What three conditions aid in the decomposition of dead organisms?

a. ____________ , b. ____________ , and c. ____________

Complete these activities.

1.48 Describe five methods of fossilization.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

1.49 Explain why mud is more likely than sand to fossilize an organism.

____

____

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Complete these activities.

1.50 Tell whether each environment is good or bad for preserving fossils, and give the reason for your choice.

a. the continental shelf opposite the mouth of a river ______________________________

____

b. plateau in Arizona ____

c. swamp in Georgia ____

1.51 Begin a fossil collection. Bring to the classroom any fossils you find. Sketch them in detail. Write on the sketch what you think they are. Compare them with pictures in a book on fossils, or a paleontology textbook. If two or more are similar, describe their points of similarity and their points of difference.

Ask other class members to add to the classroom collection. Submit sketches and descriptions to your teacher.

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If fossils are not available, sketch and label fossils from ten animal groups as they are found in a book. Secure your teacher's permission to substitute this assignment.

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CRUSTAL CHANGES

Evidence of changes in the earth's rust is abundant. Virtually every road cut and cliff display rock that has been folded and faulted. One of the tasks of the geologist is to recreate the history of an area. To determine the history, the geologist must determine the processes that changed the earth's crust. The geologist must also decide the economic significance of a change in the earth's crust in relation to the mineral resources available.

Evidence. With few exceptions, the high mountain ranges of the world are made up of rocks that were deposited and lithified beneath the sea and have since been folded and faulted. Evidence of marine deposition include the vast quantities of marine fossils in sedimentary rocks that display features typical of the marine environment. These marine rocks are now thousands of meters above where they were deposited. Less dramatic evidences are shallow water coral reefs that make up a sizable region of west Texas; seashells on the north rim of the Grand Canyon; and **algal** structures in the Helderberg Escarpment southwest of Albany, New York. In fact, *most* sedimentary rock found on continents is of marine origin. In some places the sediment is upwards of 10,000 to 15,000 meters thick. The number of fossils is greater than the population of any community of living organisms. In short, the surface of the earth has been changed since those sediments were deposited. In some instances, more than one change is indicated: rocks deposited on land overlie rocks deposited in water that overlie rocks deposited on land, and so on.

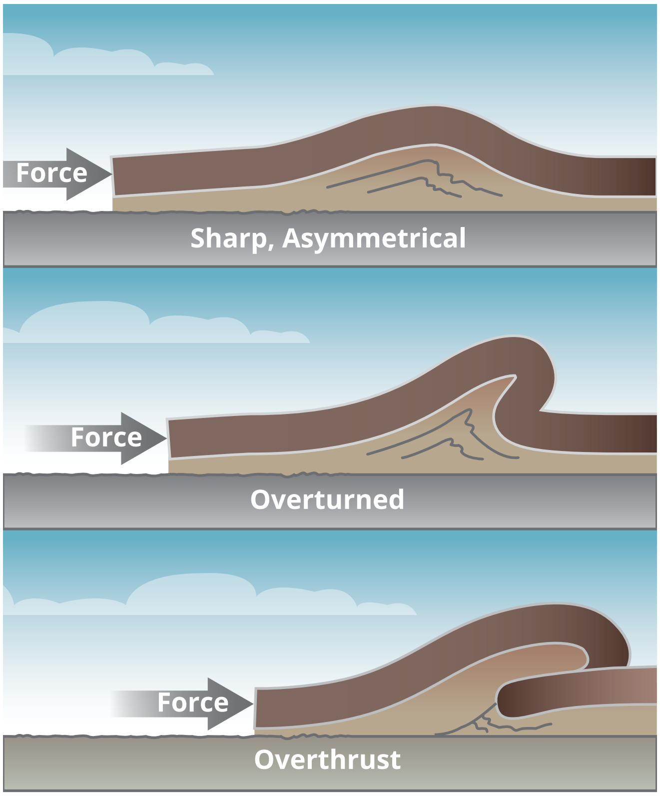

Figure 11| Thrust Faulting

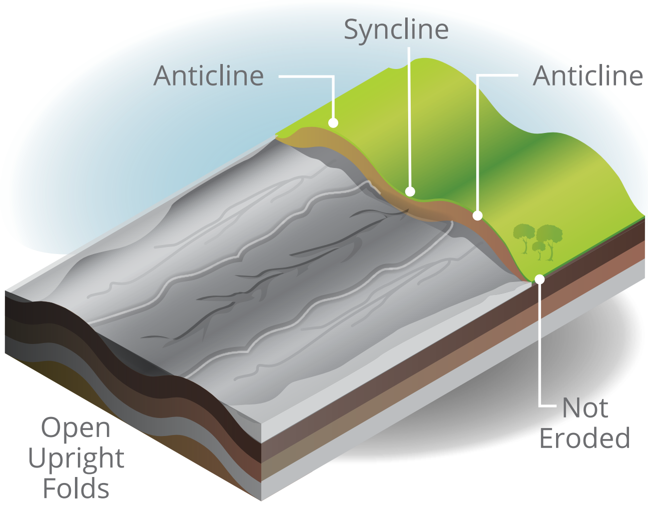

Figure 10 | Folds

Processes. Crustal changes are described by one of two terms: **orogenic** or **epeirogenic**. An *orogenic* change is one that involves deformation of the earth's crust. *Orogeny* produces folds, faults, local metamorphism, and sometimes volcanism by way of the fractured rock. The original, horizontally deposited, sedimentary rock is folded into anticlines and synclines, fractured and faulted, and perhaps intruded with igneous rock. The Appalachians, Rockies, Alps, and Himalayas display this combination of features, as do many smaller ranges.

A feature commonly observed in highly deformed regions that has puzzled geologists is *thrust faulting.* Large sections of rock have been thrust horizontally, sometimes many kilometers.

In some cases the *thrust plate* has been lifted out of sequence and now rests upon younger rock. In other cases the thrust plate is relatively undeformed.

Some regions of uplifted sedimentary rock are still horizontal and undeformed. They have undergone *epeirogeny.* The classic example of epeirogenic uplift is the Colorado Plateau in the Four Corners region of Arizona, New Mexico, Colorado, and Utah. The north rim of the Grand Canyon is a marine limestone formation some 2,500 meters (7,000 feet) above sea level. The Atlantic Coastal Plain, the lower Mississippi River valley, and the Great Plains are regions of marine sediment well above sea level.

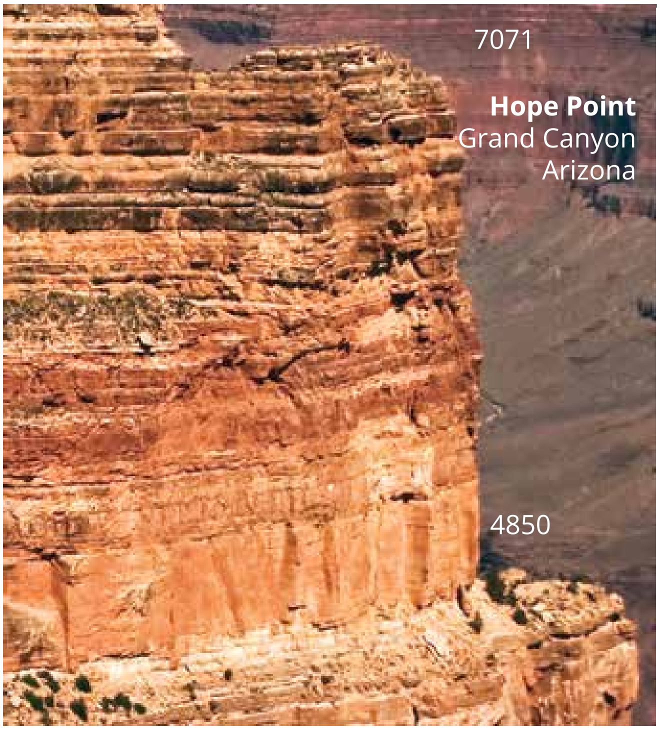

Figure 12 | Epeirogenic Uplift

Orogeny and epeirogeny are two ends of a spectrum. Any region may display both effects in varying degrees.

Economic significance. Are efforts to interpret earth history of more than just academic interest? Yes, for several reasons.

First, petroleum and natural gas originate under specific environmental conditions. Their raw materials are uncounted billions of microscopic organisms that live and die on shallow marine shelves. Rapid burial by fine sediment preserves the soft tissue. Pressure, in the absence of oxygen, converts the body fluids and gases into the fuels upon which our economy depends. The petroleum geologist looks for the environment in which petroleum forms. His methods of investigation involve complex

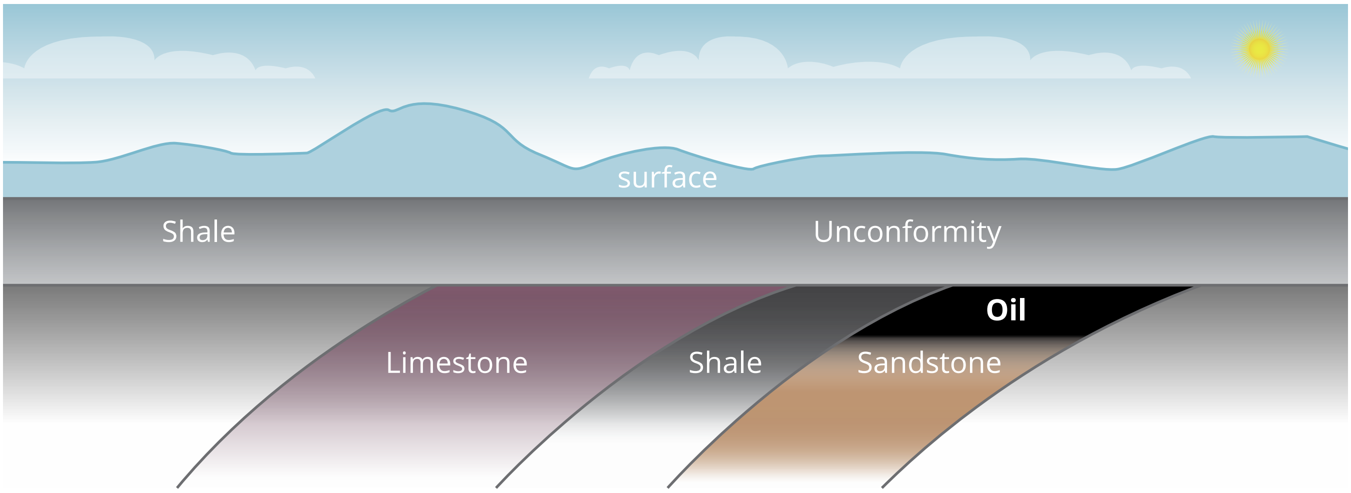

Figure 13 | Environment for Petroleum

electronic and magnetic devices that collect data from specially fitted airplanes.

When an oil well is begun, a *micropaleontologist* stays with the drillers. He examines the rock and fossils brought to the surface to determine the formations being drilled. Information is charted on a well log.

Second, a common theme of stories of the Old West is the vein of silver that ends abruptly and cannot be relocated. Silver is emplaced in the crust by ground water or by liquid left over from igneous intrusions. If the crust should then experience orogeny, the veins would be broken and possibly displaced. The mining engineer can calculate the distance and direction of movement, and the "lost" vein can be relocated. The engineer, in effect, is reconstructing the crust as it was before orogeny.

Third, civil engineers and structural geologists work together during the planning and designing of bridges, tunnels, and dams. Footings for bridges and dams must be firmly planted in rock or compacted soil that will not shift. A study of fault and fracture patterns and possible earthquake history is part of the planning.

A tragic landslide that killed hundreds of people in Italy in the mid-60s might have been prevented by better planning. The landslide dumped millions of cubic meters of rock into a reservoir. The rubble displaced water that topped the reservoir dam and sent a flood on unwarned residents of villages downstream. Geologically, the reservoir had been poorly located at the bottom of a hillside that became unstable in rainy weather.

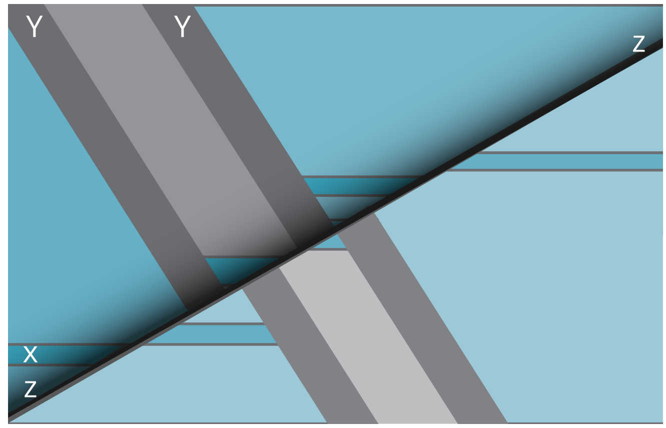

Figure 14 | A Fault-Displaced Vein

The basis of historical geology, then, is the interpretation of clues provided by rock itself. Its purpose is both academic and economic. Studying the earth's history provides an appreciation of our Creator's labor of love to give His most perfect creature a home surrounded by beauty and supplied with resources to satisfy our needs and our wants.

Complete these activities.

1.52 Cite three specific economic applications of historical geology.

a. ____________________

b. ____________________

c. ____________________

1.53 Photograph evidence of crustal deformation. Group the photos according to folded rock, faulted rock, or folded and faulted rock. Submit the collection for review. Photos should remain the property of the person who paid for them.

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Write true or false.

1.54 ____________ Most organisms that die decompose.

1.55 ____________ Mummified fossils are the most common kind of fossils.

Write true or false; the following terms are correctly paired (use a dictionary, if necessary).

1.56 ____________ lobster—vertebrate paleontology

1.57 ____________ worm—invertebrate paleontology

1.58 ____________ fern—micropaleontology

1.59 ____________ ant—invertebrate paleontology

1.60 ____________ sabre-toothed cat—vertebrate paleontology

1.61 ____________ wild-flower pollen—paleobotany

1.62 ____________ protozoans—micropaleontology

1.63 ____________ petrified wood—vertebrate paleontology

Write the letter of the correct choice.

1.64 The technique of fossilization that preserves the greatest detail is ________ .
a. petrifaction b. distillation c. mummification d. mold filling

1.65 Most high mountain ranges are composed of _________ .
a. folded sediments b. undeformed granite and metamorphics
c. flat-lying sediments d. glacial till

1.66 Crustal movement that does not involve deformation is called ________ .
a. orogeny b. faulting c. epeirogeny d. folding

1.67 Two lines of evidence that mountains were once beneath the sea are marine fossils and ________ .
a. saltwater fish in mountain lakes b. high-water marks
c. marine sedimentary rocks on mountains d. wave and beach erosion at high elevations

1.68 Most sedimentary rocks found on continents were deposited _________ .
a. on river flood plains b. in mountain ranges
c. in the oceans d. in deserts

1.69 A result of epeirogeny is ________ .
a. a mountain range b. a plateau c. a river valley d. a continental shelf

Complete these sentences.

1.70 When an organism is petrified, its organic tissue is most likely replaced by a. ______________________________or b._________________________________ .

1.71 Sand allows the passage of liquids through its pore space. The sand, therefore, is _________________ (good, poor) for fossilization.

1.72 If organic material has been completely removed, leaving a hollow space in the surrounding rock, that type of fossil is a(n) ______________________________ .

1.73 The word *petrified* means ____ .

1.74 Tracks, trails, and burrows are called __________________________ fossils.

1.75 The science of fossils is called _____________________________ .

1.76 Crustal change that includes folds, faults, and local metamorphism is called ___________________________________ .

Review the material in this section in preparation for the Self Test. The Self Test will check your mastery of this particular section. The items missed on this Self Test will indicate specific areas where restudy is needed for mastery.

SELF TEST 1

Match these items (each answer, 2 points).

1.01	_______	turbidity current	a.	mud
1.02	_______	weathered feldspar	b.	compaction
1.03	_______	2 mm to 0.0625 mm	c.	limestone
1.04	_______	clay and silt	d.	clay minerals
1.05	_______	fossil making	e.	graded bed
1.06	_______	fundamental rock unit	f.	sand
1.07	_______	rock made from conglomerate	g.	cementation
1.08	_______	reduction in volume	h.	gravel
1.09	_______	rock made from shells and coral	i.	lithification
1.010	_______	rock making	j.	petrifaction
			k.	formation

Write true or false (each answer, 1 point).

1.011 ____________ Beaches along the eastern and western coasts of North America are composed chiefly of quartz grains.

1.012 ____________ Gravel includes boulders, pebbles, and silt.

1.013 ____________ A sedimentary formation is named on the basis of its history of deposition.

1.014 ____________ Historical geology is primarily the history of the earth's crust.

1.015 ____________ Clay minerals are derived from the physical weathering of granite.

1.016 ____________ Gravel, sand, and mud are clastic sediments.

1.017 ____________ Streams have little effect on their sediment load.

1.018 ____________ Limestones result from chemical reactions in seawater.

1.019 ____________ Cementation involves the growing together of grains in contact with each other.

1.020 ____________ Paleobotany is the study of fossil insects.

1.021 ____________ Mummification frequently preserves fine detail and internal organs.

1.022 ____________ Most of the world's mountain ranges are composed of folded marine sediments.

1.023 ____________ Epeirogeny is crustal uplift without deformation.

1.024 ____________ Most sedimentary rocks found on continents were formed underwater.

1.025 ____________ Mud is more likely than sand to preserve fossils.

Write the letter of the correct choice (each answer, 2 points).

1.026 Turbidites represent an environment of ________ .
a. deep water b. low humidity
c. continental glaciers d. torrential rains

1.027 Chemical weathering has little effect on ________ .
a. mica b. feldspar c. quartz d. basalt

1.028 Limestones originate ________ .
a. on sea floors b. in deserts c. on mountaintops d. in flood plains

1.029 The fundamental sedimentary unit is the ________ .
a. group b. formation c. member d. bed

1.030 The opposite of lithification is ________ .
a. transportation b. weathering c. compaction d. cementation

1.031 Limestone originates because of ________ .
a. chemical reaction
b. chemical weathering
c. physical weathering
d. biological processes

1.032 Conglomerate is rock formed from ________ .
a. gravel
b. sand
c. silt
d. clay

1.033 The study of fossil mammals is ________ .
a. invertebrate paleontology
b. vertebrate paleontology
c. micropaleontology
d. paleobotany

1.034 The fossilizing process that replaces organic matter with silica or calcite is ________ .
a. petrifaction
b. distillation
c. mummification
d. mold filling

1.035 Orogeny is the cause of ________ .
a. high winds
b. high mountains
c. high expenses
d. high flying

Complete these activities (each problem, 5 points).

1.036 Explain why sedimentary rocks could not have been the first rocks on earth.

____

____

____

1.037 Complete this chart.

Sediment		Sedimentary Rock
sand	→	a.
gravel	→	b.
silt	→	c.
clay	→	d.
shell fragments	→	e.

52/65 **SCORE** ____________ **TEACHER** ____________ ____________
initials date

NOTES

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PUBLICATIONS

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