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SCIENCE

STUDENT BOOK

9th Grade | Unit 4

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SCIENCE 904

Historical Geology

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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.

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

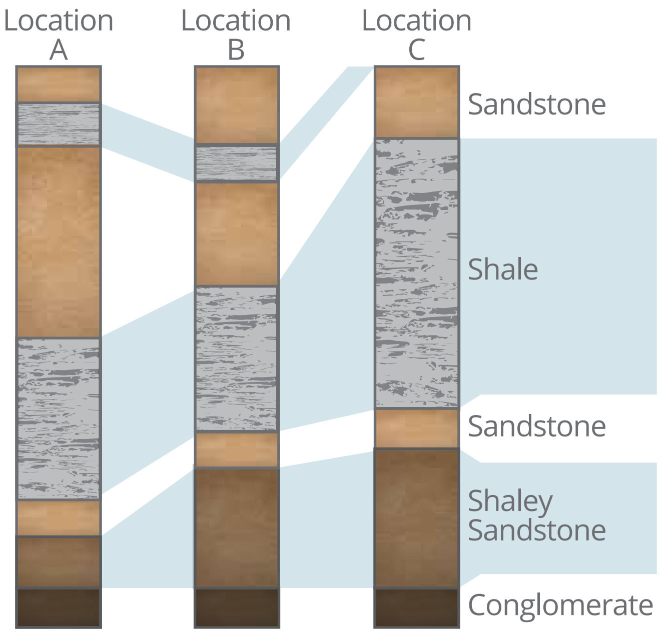

Figure 1 | Sedimentary Sequences

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.

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?

____

____

____

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____

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.

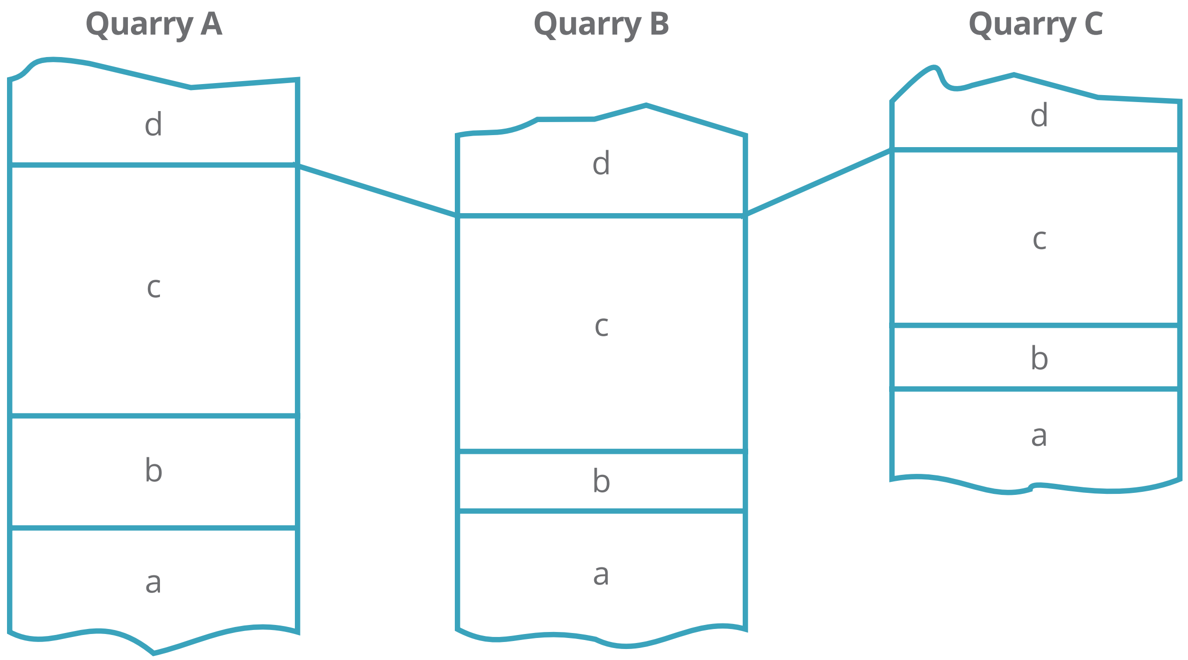

Figure 2 | Rock Sequences

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

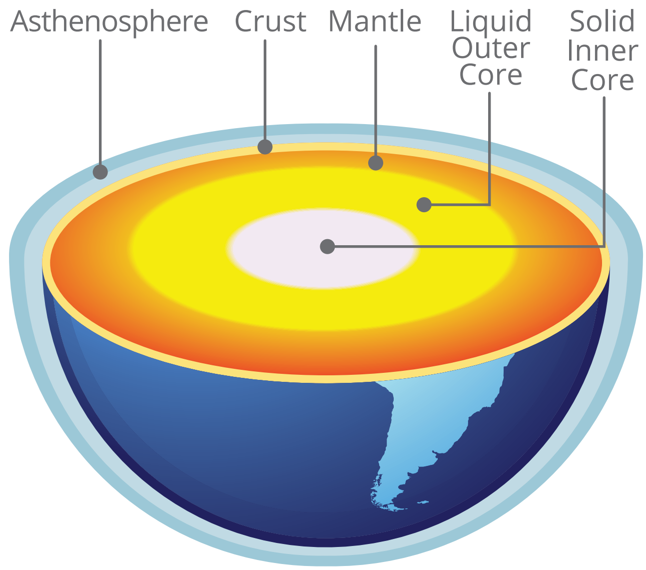

Figure 3 | The Thin Crust

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

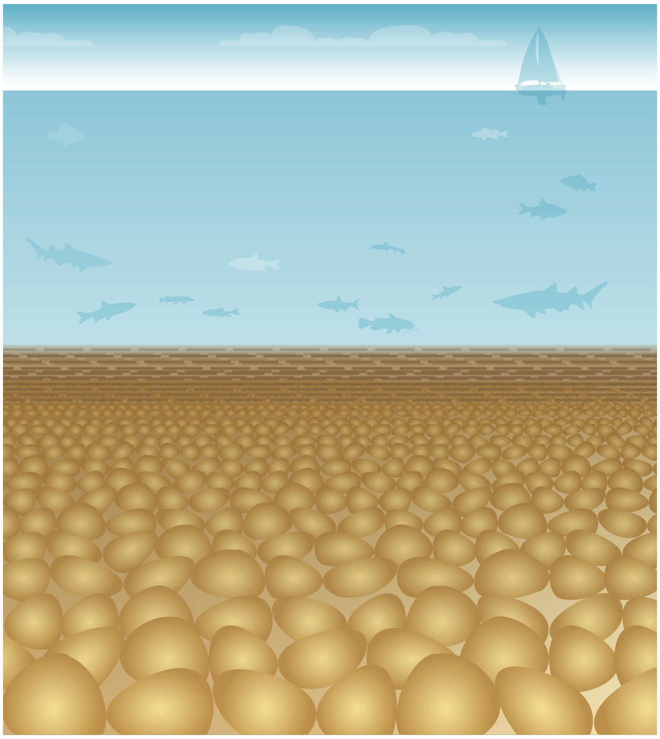

Figure 4 | Graded Bed

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

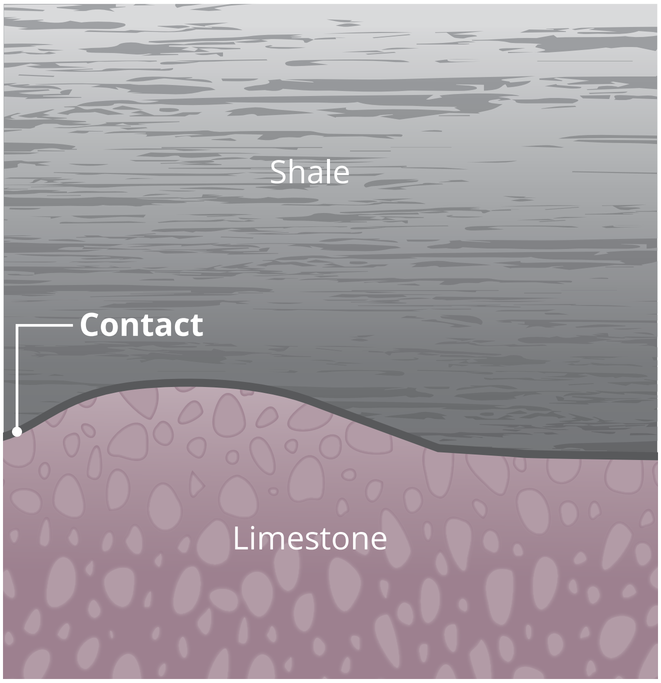

Figure 5 | Formation Contact

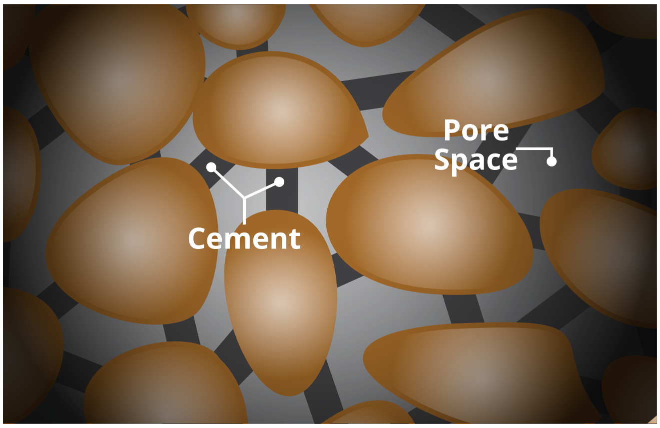

Figure 6 | Cement Between Sand Grains

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** ____________ ____________
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