CHAPTER 4 THE SEA FLOOR

Key Concepts

Major Concept (I) *The early concepts of the ocean basins envisioned them as being static depressions filled with the sediment eroded from the continents. It was generally believed that the sea floor was flat and featureless.*

Related or supporting concepts:

- Early geologists believed the sea floor was flat for two reasons:
  a. the sea floor was not tectonically active so there were no mountains or faults, and
  b. sediment carried to the oceans would blanket the sea floor and smooth out any irregularities.
- With time it became important for shallow coastal waters to be surveyed accurately for navigational purposes. In this way, some of the irregularity of the sea floor was revealed.
- Routine mapping of the sea floor did not occur until after WWII when some of the technology developed for the war could be applied to peaceful, scientific purposes.
- From the 1950s on to the present day we have learned about the dynamic nature of the sea floor and the abundance of geologic features in the ocean basins.

Major Concept (II) *The sea floor has the same major geologic features that we see on land, including mountains, valleys, plateaus, and faults.*

Related or supporting concepts:

- Although the sea floor has the same types of structures we see on the continents, they are often of grander proportions than on land because of less severe erosional forces.
- Landforms are modified relatively quickly by mechanical means such as wind, running water, rain, and moving ice. In addition, they can be chemically eroded and broken down by repeated changes in temperature either seasonally or daily.
- On the sea floor many of the active erosional agents on land are not found. There is no wind, moving ice, or rainfall. Temperatures are essentially constant on the sea floor.
- The major erosional agents in the oceans are waves and currents, and even these are able to act quickly only in shallow, near-coastal waters.
- Erosion in the oceans is very slow. One of the most important modifying processes is the blanketing of the sea floor with sediment that settles out of the water column.
- Take a look at figure 4.1 in your text and you will see that typical profiles across the ocean basins reveal a ruggedness to the topography that is no different from the continents.

Major Concept (III) *The edges of the continents continue seaward to form the continental margin.*

Related or supporting concepts:

- There are two different kinds of continental margins, passive and active. Passive continental margins are not plate boundaries. Active continental margins are plate boundaries.
- Passive continental margins can be subdivided into the following distinct regions:
  - a. continental shelf,
  - b. shelf break,
  - c. continental slope, and
  - d. continental rise.
- Along active continental margins the continental slope commonly descends into a deep ocean trench and there is no continental rise unless large amounts of sediment eroded from the continent have filled the trench.
- A profile across a typical passive continental margin is shown in figure 4.2 in your text.
- The continental shelf region has the following characteristics:
  - a. consists of continental material,
  - b. relatively flat lying with average gradients of about 2 m/km,
  - c. varies in width from tens of meters to over 100 km with an average width of about 65 km, and
  - d. slopes seaward to a maximum depth at their outer edge that varies from 35 m to 350 m, averaging about 130 m.
- With the rising and falling of sea level in response to the ice ages, the continental shelves have been periodically exposed to the air and submerged. When sea level was low they were subject to continental erosional processes as well as the deposition of sediments by rivers and streams.
- Some continental shelves are covered with thick deposits of relict, or old, continental sediments. Other shelves have been stripped of sediments by powerful currents that flow over them now.
- The width of the shelf is typically related to the coastal relief of the land. Where there are mountains near the shore the shelf is often narrow, while low-lying coastal regions are often adjacent to broad continental shelves.
- The continental shelves are thought to be created by a number of different processes including:
  - a. the constant erosion of the coast by wave action, and
  - b. the trapping of sediment behind structural dams created by reefs, volcanic mounds, salt domes, and upthrown blocks of rock.
- The outer edge of the shelf is marked by a distinct change in slope of the sea floor called the continental shelf break.

- Beyond the shelf break the continental margin continues across a region called the continental slope that descends at an average gradient of about 70 m/km.
- The continental slope is usually too steep for significant amounts of sediment to accumulate on it.
- The slope will generally extend downward to depths in excess of 3000 m except where there is a deep ocean trench along the continental margin, in which case it may continue to depths of 8000 m or more.
- The slopes are periodically cut by massive rifts called submarine canyons. These canyons can extend upward across the shelves.
- Submarine canyons are thought to have been cut initially by rivers during low stands of sea level. They are V-shaped in cross section and may have profiles similar to the Grand Canyon in terms of width and depth (take a look at fig. 4.4).
- Submarine canyons can direct the flow of avalanches of dense sediment-water mixtures called turbidity currents that flow down slope and onto the sea floor to build the continental rise. When these currents exit the bottom of the canyon they spread out and the suspended sediment particles are deposited in order of size with the largest falling out first. This creates deposits called turbidites with graded bedding; largest particles on the bottom and smaller ones on top (see fig. 4.5).
- In 1929 a large turbidity current broke a series of trans-Atlantic telephone cables south of New Foundland. The turbidity current moved at a speed of as much as 80 km (50 mi)/hr down the continental slope and about 24 km (15mi)/hr on the more gently sloping continental rise. It traveled a distance of about 650 km (400 mi).
- The continental rise is a wedge of sediment with an intermediate gradient averaging about 9 m/km that is built up by repeated turbidite deposits.
- The continental rise is seen frequently in the Atlantic and Indian oceans but not the Pacific because of the presence of numerous deep trenches.

Major Concept (IV) *The deep ocean floor is a vast region covering about 30 percent of the planet's surface. It extends in depth from about 4000 to 6000 meters (13,000 to 20,000 ft).*

Related or supporting concepts:
- The deep sea floor is often relatively smooth near continental margins. This is due to the covering of any irregularities by large amounts of sediment carried to the oceans. This broad, flat part of the deep ocean is called the abyssal plain.
- With increasing distance from the continents the sediment cover can thin and irregularities in the sea floor will be more apparent.
- Major features of positive relief include abyssal hills and seamounts. Abyssal hills are volcanic features less than 1000 m (3300 ft) high and seamounts are volcanic features taller than 1000 m (see fig. 4.6). Abyssal hills may be the most common geologic feature on earth, covering about 50 percent of the Atlantic and 80 percent of the Pacific sea floors. They are also known to be widespread in the Indian Ocean but have

not been surveyed there as extensively.

- Other common features in warm water ocean regions are reef structures built by corals. Coral reefs require warm, clear water at shallow depths because they grow in association with a single-celled plant that requires sunlight for photosynthesis.
- There are three stages in the life history of a coral reef. These are shown in figure 4.7 as:
    a. the fringing reef that grows around the edge of an island,
    b. the barrier reef that forms as the island sinks due to subsidence and creates a lagoon between the reef and the island, and
    c. the formation of a roughly circular reef called an atoll that surrounds a central lagoon formed when the island sinks beneath the surface.
- This progressive development was first suggested by Charles Darwin during his voyage on the HMS *Beagle* from 1831 - 36.
- As islands sink they will have their tops eroded nearly flat by wave action. Continued subsidence then produces flat-topped seamounts called guyots. Many of them have coral debris on them proving that they were once near the surface.
- Guyots are found most frequently in the Pacific Ocean at depths from 1000 to 1700 m (3300 to 5600 ft) beneath the surface. Many guyots are found at a depth of 1300 m (4300 f t) beneath the surface.
- Mechanisms responsible for the subsidence of islands are discussed in the next chapter.

Major Concept (V) *The longest continuous mountain system on the planet winds its way through the ocean basins in a series of connected ridges and rises often called the mid-ocean ridge system.*

Related or supporting concepts:

- The mid-ocean ridge system is often described as being like the stitching on a baseball. It extends throughout the oceans for a combined length of about 65,000 km (40,000 mi). This is shown schematically in figure 4.8.
- The ridge system is about 1000 km (600 mi) wide and ranges in height above the surrounding abyssal plain 1000 to 2000 m (3500 to 7000 ft).
- The cross-sectional profile of the system varies along its length. Where it is steep it is called a ridge and where it is more gentle it is called a rise. Ridges are dominant in the Atlantic and Indian oceans while rises are more frequently found in the Pacific Ocean.
- Along the ridges the axis of the ridge is often marked by a deep central rift valley 15 to 50 km (9 to 30 mi) wide and 500 to 1500 m (1500 to 5000 ft) deep.
- The axis of the system is volcanically and seismically active.
- On closer inspection the ridge system is not continuous. It is broken into segments that are offset from one another by faults called transform faults. Transform faults are perpendicular to ridge segments and may extend beyond the region between ridge segments as fracture zones.

- The oceanic ridge system effectively divided the deep sea floor into a number of semi-isolated basins that can trap and direct the movement of bottom water.

Major Concept (VI) *Massive gashes cut across the sea floor in some areas. These narrow, elongate deeps are called deep-ocean trenches.*

Related or supporting concepts:

- Trenches are most common in the Pacific Ocean, as can be seen in figure 4.9. They rim the Pacific basin and are associated with active volcanic island arcs and active volcanism along continental margins.
- The deepest spot in the oceans is found in the Challenger Deep of the Mariana Trench at a depth of 11,020 m (36,150 ft).
- Trenches vary in length up to a maximum of 5900 km (3700 mi) in the case of the Peru-Chile Trench.
- The Atlantic Ocean has only two short trenches and the Indian Ocean has one trench of intermediate length.
- Trenches are relatively narrow, approximately 100 to 200 km, and have steep walls. The wall of the trench facing the open ocean is generally less steep than the other one.

Major Concept (VII) *Ocean depths and seafloor features have been measured in a variety of increasingly accurate and sophisticated ways throughout time.*

Related or supporting concepts:

- Ocean depths are usually reported in one of two different units, the meter or the fathom. A fathom is equal to six feet.
- The first deep measurements of the seas were made using a lead weight attached to a rope that was marked in fathoms. The end of the weight was often hollowed out and filled with grease so that particles of sediment would be embedded in it when it struck bottom and could later be recovered when the weight was retrieved. This was a reasonably accurate method in shallow water and could even help sailors navigate by knowing what type of bottom material was below.
- In deep water this method was not very efficient because of the weight of the line and the time required to lower it. Consequently, a slightly modified technique was employed that used piano wire and a cannonball. The wire was light and the ball was so heavy that it would travel downward more rapidly and was easier to sense when it hit the bottom.
- In very deep water, it could still take as long as 8 to 10 hours to take a single sounding, or measurement of depth. By 1895 there were still only about 7000 measurements in water deeper than 2000 m and only 550 in water deeper than 9000 m. This was clearly inadequate to give geologists any understanding of seafloor topography.
- The echo sounder, or depth recorder, was invented in the 1920s and tested on board

the Meteor expedition in the Atlantic Ocean. An example of an echo sounder record is shown in figure 4.11.

- The echo sounder emits a pulse of sound that travels down through the water and reflects from the sea floor to return to the surface. The velocity of propagation of sound in seawater is nearly constant, so by timing how long it takes for the sound to travel the round trip from the ship to the bottom and back, it is easy to compute depth.
- The great advantage of the echo sounder is that measurements can be taken continuously and with great accuracy while the ship is under way.
- We currently have fairly detailed knowledge of submarine features thanks to precision depth recorders, cameras, deep-towed sonar, and manned submersibles.
- Large scale seafloor features can be detected by observing variations in the height of the sea surface due to changes in gravity using satellites (fig. 4.12).
- The excess mass of large seamounts and ridges creates a gravitational attraction that draws water toward them, resulting in an elevation of the sea surface. Sea level is elevated by as much as 5 m (16 ft) over large seamounts and 10 m (33 ft) over ocean ridges.
- The lack of mass due to deep sea trenches produces a weaker gravitational attraction where water will be drawn away from the region by areas of greater mass elsewhere. This creates a depression of the sea surface of as much as 25 to 30 m (80-100 ft).
- These changes in elevation occur over tens to hundreds of kilometers so the slopes involved are very gentle.

Major Concept (VIII) *Sediments can also be classified by size. Size is a very important factor in a number of other respects including the rate at which particles will sink, the probability a particle will be dissolved before it reaches the bottom, the distance it is likely to travel from its source, and the energy level of its area of deposition.*

Related or supporting concepts:

- Sediment particles can be classified by diameter as indicated in table 4.1.
- There are three major subdivisions of particle size, each of which is further broken down into a number of smaller divisions. From largest to smallest these are:
  - a. gravel,
    - i. boulder
    - ii. cobble
    - iii. pebble
    - iv. granule
  - b. sand,
    - i. very coarse sand
    - ii. coarse sand
    - iii. medium sand
    - iv. fine sand

v. very fine sand

c. mud.

i. silt

ii. clay

- Sediments are well sorted if nearly all the particles are of the same size and poorly sorted if sizes vary markedly. In general, well sorted sediments have been subjected to high energy environments where fast moving water has been able to carry away small particles and leave larger ones behind.
- Sinking rates are generally related to particle size. Larger particles sink at faster rates.
- Sand-sized particles may settle to the deep sea floor in a matter of days while it may take clay-sized particles over 100 years.
- The slower the sinking rate the more likely a particle will be transported by currents or dissolved before it reaches the bottom.
- Very small particles can sink at faster rates due to two different effects:
  a. if they are charged particles they can attract each other and clump into larger masses that will sink more rapidly, or
  b. organisms may ingest large numbers of smaller particles and then expel them in fecal pellets large enough to sink to the bottom in days rather than several decades. It is estimated that as many as 100,000 microscopic shells of tiny organisms can be packaged in a single fecal pellet.

Major Concept (IX) *Marine sediment can also be classified by where it accumulates (fig. 4.16).*

Related or supporting concepts:

- Marine sediment can be classified as either neritic or pelagic.
- Neritic sediments are found near continental margins and islands.
- Most neritic sediments are eroded from rocks on land and transported to the coast by rivers and streams.
- As much as 15 billion metric tons of sediment are carried to the oceans annually.
- Accumulation rates are highly variable. In quiet bays they may be as high as 500 cm (200 in)/yr. On continental shelves and slopes they may be 10 to 40 cm (4 to 16 in)/1000 yrs.
- Pelagic sediments accumulate on the deep sea floor. They are typically very fine-grained.
- The thickness of pelagic sediments increases with increasing age of the sea floor, or increasing distance from the ridge.
- An average accumulation rate for pelagic sediment is 0.5 to 1.0 cm (0.2 to 0.4 in)/1000 yrs.
- The average thickness of pelagic sediment on the deep sea floor is 500 to 600 m (1600 to 2000 ft). It would take about 100 million years for this much pelagic sediment to accumulate.

Major Concept (X) *Another method of classifying sediment is by grouping it according to the origin and chemistry of the particles that make up the sediment.*

Related or supporting concepts:

- There are four major sources of sediment particles:
  a. pre-existing rocks,
  b. dissolved material in seawater,
  c. space, and
  d. organisms.
- Lithogenous sediment is derived from pre-existing rocks that are broken down into small particles by erosion. These particles are then transported by wind, running water, moving ice, and gravity.
- Lithogenous sediments are also commonly called terrigenous sediments.
- The chemical composition of lithogenous sediment is controlled by the chemistry of their source rocks. Most of these sediments have high concentrations of quartz because it is abundant and highly resistant to erosion.
- Lithogenous sediment is the dominant type of neritic sediment because the supply of sediments from the continents simply overwhelms all other types of material.
- Abyssal clay is lithogenous pelagic sediment composed of at least 70% by weight clay-sized particles.
- Abyssal clay accumulates very slowly and is the dominant sediment type only when there is a lack of other sediment types to dilute it, not because it accumulates rapidly.
- These clays are often rich in iron that oxidized in the water, coloring the sediment red. They are often called red clays (fig. 4.14a). The distribution of red clay is shown in figure 4.15.
- Sediments derived from organisms are called biogenous sediments.
- Biogenous sediment may include shell and coral fragments as well as skeletal remains of marine organisms of all sizes, but mostly single-celled plants and animals that live in surface waters.
- Most deep water biogenous material is composed of the skeletal remains of single-celled organisms (see fig. 4.16).
- Biogenous sediment has two different chemistries:
  a. calcareous, which is composed of shell material or calcium carbonate, and
  b. siliceous, which is composed of silicon dioxide and is very hard.
- By definition, if deep-sea sediment contains over 30 percent biogenous material by weight it is called an ooze (either calcareous ooze or siliceous ooze depending on chemistry).
- Calcareous skeletal parts are formed by a variety of organisms including:
  a. animals such as foraminifera and pteropods, and
  b. plants like the single-celled coccolithophores.

- The solubility of calcium carbonate is a function of depth and temperature. It tends to dissolve more rapidly in colder water and deeper water.
- The depth at which calcareous material first begins to dissolve is called the lysocline.
- The depth at which the amount of calcareous material preserved falls below 20% of the total sediment in called the carbonate compensation depth (CCD).
- Calcareous ooze tends to accumulate at depths above the CCD and is generally absent at depths below the CCD.
- The CCD has an average depth of about 4500 m (14,800 ft). It tends to be shallower in the Pacific Ocean than in the Atlantic.
- Siliceous skeletal parts, or tests, are created by small photosynthetic organisms called diatoms and animals called radiolaria (fig. 4.16b).
- The depositional pattern of siliceous tests is opposite that of calcareous tests.
- Siliceous tests will dissolve at all depths but they dissolve most rapidly at shallow depth in warm water.
- Siliceous tests are preserved on the sea floor only below areas of high biological productivity in the surface water.
- Hydrogenous sediment is formed when material precipitates out of solution in seawater. Examples include:
    a. carbonates such as limestone,
    b. phosphorites formed as crusts or nodules when phosphorus precipitates,
    c. metal rich sulfides at hydrothermal vents along ridges, and
    d. manganese nodules that are also rich in iron, copper, nickel, and cobalt (fig. 4.14). Manganese nodules form very slowly, growing by 1 - 200 mm/million years (1000 times slower than other pelagic sediments), and often form around a hard "seed" such as a small bone or tooth. They form in areas where there is little other sediment or strong currents to keep them from being buried. They are most abundant in the Pacific ocean but are also found in the Atlantic and Indian Oceans.
- Cosmogenous sediment is formed from iron-rich particles that constantly fall through the atmosphere from space. Most of these dissolve as they sink slowly through the water.
- Cosmogenous sediment particles typically have rounded or teardrop shapes due to partial melting as they pass through the atmosphere.

Major Concept (XI) *To study marine sediments, geologists must retrieve samples using different types of equipment designed for specific sampling conditions and jobs.*

Related or supporting concepts:

- Large rocks or shell material lying on the surface of the sea floor are best recovered using a dredge. Dredges typically have wire or chain baskets and are dragged along the bottom for a distance before being retrieved (see fig. 4.18).

- Grab samplers can be lowered to the bottom where they will close and scoop up a sample of loose sediment (see fig. 4.19).
- Deep samples of sediment can be obtained using different coring devices. Corers consist of pipes with weights attached on the top that force the pipe stem into the sediment (see fig. 4.20a-c). The pipes vary in diameter from about 6 to 20 cm and in length from 1 to 20 m (3 to 60 ft).
- Box corers are designed to embed a metal box in the sediment and then close off the bottom. These devices are excellent for retrieving a relatively shallow sample of material without disturbing the layering too much (see fig. 4.20d).
- The longest sediment samples must be retrieved by drilling.

Major Concept (XII) *With increasingly sophisticated mining technology and growing demands for natural resources it is becoming increasingly important to understand what natural resources exist in the seas and where they are concentrated.*

Related or supporting concepts:

- The seas have been mined for centuries for their natural resources. Historically, the Greeks are known to have mined lead and zinc by digging shafts outward from land under the ocean. In medieval times this same technique was used by Scottish miners to recover coal.
- The feasibility of mining any particular product from the oceans depends on:
    a. the existence of a market for the material,
    b. adequate mining technology to recover the material, and
    c. a cost effective mining operation.
- Volumetrically, the largest mining operation in the oceans is for sand and gravel. This is mined from coastal areas and used in the construction industry.
    a. This is a low cost product that is used in areas where land deposits are scarce and shipping costs are low.
    b. Current annual world production is about 1.2 billion metric tons.
    c. This is the only material the United States currently mines from the oceans.
- Sand and gravel can also be mined for minerals that are enriched in it such as iron in Japan and tin in Southeast Asia.
- Phosphorite is plentiful in nodules and in muds and sands on the continental shelf and slope in many parts of the world, including regions offshore the United States. The phosphates produced from it are used for fertilizer.
- Large reserves of sulfur have been found in the Gulf of Mexico and the Mediterranean Sea. It is less economical to mine it from the oceans now when it can be recovered from pollution control equipment.
- Coal seams that extend under the sea are mined in Japan.
- By far the most valuable commodities currently mined from the oceans are oil and gas, which account for about 95 percent of the recovered mineral value. Huge reserves have been found and are being mined, while many other areas that may have high

potential have not yet been evaluated. Deposits along continental margins account for about one-third of the world's estimated oil and gas reserves.

- Recovering oil and gas offshore costs three to four times as much as similar operations on land, but the size of the fields are great enough to make it economical.
- A wide variety of valuable minerals are known to be concentrated in manganese nodules including manganese, copper, nickel, and cobalt. Currently, there is not much of a market for these metals, and hence there are no serious efforts underway to mine them at this time.
- Spreading centers have proven to have large sulfide deposits formed by hydrothermal activity. Water percolates into the rock through fissures and is heated to very high temperatures, allowing it to leach minerals from the rock. When this water recirculates to the sea floor, the materials in solution precipitate out and form sulfide deposits rich in such minerals as zinc, iron, copper, and others. There is still a lot to be learned about these deposits, including ways to mine them economically.
- In recent years there has been an increasing interest in gas hydrates trapped in deep marine sediments.
- Gas hydrates are a combination of natural gas, primarily methane (CH_4), and water that form a solid, ice-like structure under pressure at low temperature.
- Gas hydrates are a potential source of energy. They may also contribute to slumping along continental margins and they may play a role in climate change.
- The amount of methane stored in gas hydrates is believed to be about 3000 times the amount currently in the atmosphere. Since methane is a greenhouse gas, its release from hydrates could effect global climate.

Major Concept (XIII) *The potential value of the ocean's mineral resources and the limited number of countries that could conceivably mine them have caused a number of laws and treaties to be drafted among nations in an effort to guarantee all countries a fair share of the potential profits.*

Related or supporting concepts:

- There is a recognized 200 mile exclusive economic zone extending offshore the world's coastlines. Within this zone, nations have exclusive mineral rights. In the case of manganese nodules in particular, and other mineral deposits in general, much of the sea's wealth lies outside these zones.
- Developing nations want to be able to share in the profits enjoyed by those few countries capable of mining the deep seas.
- The United Nation's Law of the Sea conferences were held periodically over a span of nearly a decade to produce an international agreement concerning marine mining.
- The Law of the Sea Treaty was completed in 1982. It recognized manganese nodules as a global resource and established a regulating agency that would license mining operators and distribute the profits among developing nations.
- The United States did not sign the U.N. Law of the Sea Treaty.

- Given the present cost of recovering these materials and the depressed international market for metals, there are no large scale mining operations underway and it may be quite some time before there are.

Key Terms and Related Major Concepts

At the back of the chapter in your book there are a number of key terms. You should be able to find the following terms referenced in the major concept indicated in parentheses.

sediment(II,X)	fringing reef(IV)	biogenous sediment(X)
trench(III,VI)	barrier reef(IV)	ooze(X)
continental margin(III)	atoll(IV)	calcareous ooze(X)
continental shelf(III)	rift valley(V)	siliceous ooze(X)
continental shelf break(III)	transform fault(V)	red clay(X)
continental slope(III)	mid-ocean ridge system(V)	abyssal clay(X)
submarine canyon(III)	island arc(VI)	lysocline(X)
turbidity current(III)	fathom(VII)	carbonate compensation
turbidite(III)	echo sounder(VII)	depth (CCD) (X)
continental rise(III)	depth recorder(VII)	terrigenous sediment(IX)
subsidence(IV)	lithogenous sediment(X)	neritic sediment(IX)
abyssal plain(IV)	hydrogenous sediment(X)	pelagic sediment(X)
abyssal hill(IV)	phosphorite(X,XIII)	dredge(X)
seamount(IV)	manganese nodule(X,XIII)	grab sampler(XI)
guyot(IV)	cosmogenous sediment(X)	corer(XI)

Test Your Understanding With The Following Questions:

FILL IN THE BLANK

1. The continental ________________ is the flattest section of the continental margin.
2. Submarine ______________________ cut across the continental slope and channel sediment to the sea floor.
3. _____________________________ currents flow down submarine canyons.
4. A flat topped seamount is called a ________________.
5. _____________________________ faults offset segments of ridge crest.
6. An _____________ contains at least 30 percent biogenous material by weight.
7. ______________________ ____________________ are hydrogenous sediments that are rich in a number of different metals.
8. Sediment that is deposited on the continental shelf is called ______________________

sediment.

9. Wire or chain baskets designed for recovering loose rocks from the bottom are called ________________.

10. The United States currently mines _____________ and ____________________ for use in the construction industry.

TRUE - FALSE

1. In general, submarine geologic features are modified more slowly by fewer erosional processes than their equivalent features on land.
2. Continental shelves along rugged coastlines are often very broad.
3. Deep ocean trenches are found primarily in the Pacific Ocean.
4. Submarine canyons have physical dimensions that may be similar to the Grand Canyon.
5. Smaller sized sediment particles often travel farther from their source.
6. Abyssal hills are found over about 35 percent of the Pacific sea floor.
7. Coral reefs require cool, shallow water.
8. Pteropods are animals that create calcareous hard parts.
9. Silicon dioxide is undersaturated in the oceans because it is very hard to dissolve.
10. Calcareous ooze is usually found at relatively shallow depths.

MULTIPLE CHOICE

1. Erosional processes that modify marine structures include:
   a. waves
   b. currents
   c. wind
   d. chemical reactions
   e. a, b, and d above
2. Which of the following is a part of the continental margin?
   a. the shelf
   b. the slope
   c. the shelf break
   d. the rise
   e. all of the above
3. The steepest part of the continental margin is the:
   a. shelf break
   b. slope
   c. shelf
   d. rise
   e. none of the above
4. Seamounts are objects that are taller than:
   a. 500 m
   b. 1500 m

c. 1000 m
d. 1200 m
e. 400 m

5. The abyssal plain covers what percentage of Earth's surface?
   a. 30
   b. 50
   c. 10
   d. 75
   e. 15
6. Sediment that is composed of particles originating from organisms is called:
   a. lithogenous
   b. cosmogenous
   c. hydrogenous
   d. biogenous
   e. equestrian
7. The final stage in the life of a coral reef is the formation of:
   a. a fringing reef
   b. an atoll
   c. a barrier reef
   d. a guyot
   e. a lagoon
8. The combined length of the ridge system in the oceans is about:
   a. 10,000 km
   b. 50,000 km
   c. 65,000 km
   d. 30,000 km
   e. 45,000 km
9. Siliceous oozes are examples of ______________________ sediments.
   a. hydrogenous
   b. biogenous
   c. cosmogenous
   d. terrigenous
   e. lithogenous
10. Deep-ocean sediment accumulates at the rate of about ____________ cm/1000 years.
   a. 10 - 25
   b. 5 - 20
   c. 30 - 40
   d. 12 - 15
   e. 0.5 - 1.0

Answer Key for 'Key Terms' and 'Test Your Understanding'

FILL IN THE BLANK

1. shelf
2. canyons
3. turbidity
4. guyot
5. transform
6. ooze
7. manganese nodules
8. neritic
9. dredges
10. sand, gravel

TRUE - FALSE

1.T 2.F 3.T 4.T 5.T 6.F 7.F 8.T 9.T 10.T

MULTIPLE CHOICE

1.e 2.e 3.b 4.c 5.a 6.d 7.b 8.c 9.b 10.e