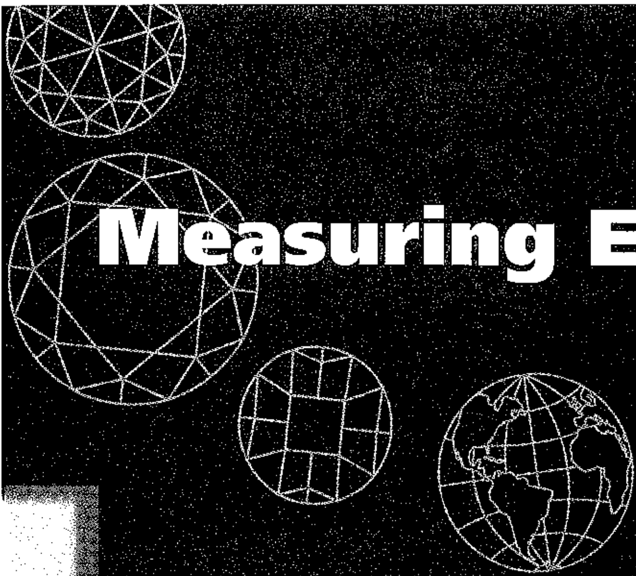


Measuring Earth

TOPIC 2

How Scientists Study Measuring Earth

Would you consider the crust of your toast part of your plate?

You wouldn't think that the crust of toast you left on your plate at breakfast is part of the plate you eat from. If you use the same concept for Earth's crust, you would jump to the conclusion that the crust is separate from any other section. Using this erroneous belief, some science periodicals have used the term "crustal plates." Do you think this is a scientifically accurate term?

Actually, there is no such thing as a "crustal plate" in Earth Science. Earth's plates are much thicker than average crust, and incorporate the crust and the uppermost mantle, often called the rigid mantle. The crust of Earth is mineralogically different than the mantle below it, but the physical properties of rigidity and solidness of the crust and the uppermost mantle are very similar. Thus, the crust and the uppermost mantle are grouped together as Earth's lithosphere. Therefore, there are *lithospheric plates*, or tectonic plates, and not "crustal plates."

TOPIC 2

Measuring Earth

Vocabulary

atmosphere	field	meridian of longitude
contour line	gradient	model
coordinate system	hydrosphere	pauses (of atmosphere)
crust	isoline	prime meridian
Earth's interior	latitude	profile
elevation	lithosphere	topographic map
equator	longitude	

Topic Overview

People have always wanted to know about where they live, be it Earth in general, or their part of their country. In this topic you will learn about the basic dimensions of Earth and its layered structure and composition. You will also learn about its spheres, and how to locate and model Earth positions and landscape features. People have struggled for thousands of years to find accurate and reproducible methods of locating specific positions on Earth's surface to find natural resources, decide who owns what land, and determine where crops can be grown well. The problem of how to find positions on Earth's surface has largely been solved by the latitude and longitude system—studied in this topic—coupled with the Global Positioning System (GPS), which uses measurements from Earth-orbiting satellites.

Size and Shape of Earth

Earth's shape is very close to being a perfect sphere. The actual shape is of a sphere that has a slight flattening at the polar regions and a 0.3 percentage bulging at the equatorial region. The human eye cannot detect this distortion from a perfect sphere, even in the most accurate globe models of Earth. A **model** is a way of representing the properties of an object or system. A model may be an object, such as a globe representing Earth, or a drawing, diagram, graph, chart, table, or mathematical formula or equation.

Evidence of Earth's spherical shape includes photographs taken from space and the way ships appear to sink as they travel past the horizon. Other evidence is the similarity of the strength of gravity at sea level all over Earth's surface. Besides being very close to a perfect sphere, Earth's surface is very smooth (has very little relief) compared to its diameter. This smoothness is evident in any photographs of Earth taken from space.

Figure 2-1 illustrates some of the basic dimensions of Earth's surface below the atmosphere. Earth's surface is the top of the liquid portion or the solid portions of Earth—described later in this topic.

Spheres of Earth

Earth is composed of a series of spheres held together by gravity and thus arranged from lowest to highest density moving towards Earth's center. Table 2-1 compares the spheres and Figure 2-2 is a model of this arrangement of spheres. There is no agreement as to the exact thickness of the atmosphere. The line in the model indicating Earth's surface is actually too thick to represent the hydrosphere/ocean average depth. The divisions of the atmosphere and their interfaces—the pauses—are also found with some of their properties in Selected Properties of Earth's Atmosphere in the *Earth Science Reference Tables*. The average chemical compositions of some of these spheres is shown in Average Chemical Composition of Earth's Crust, Hydrosphere, and Troposphere in the *Earth Science Reference Tables.*

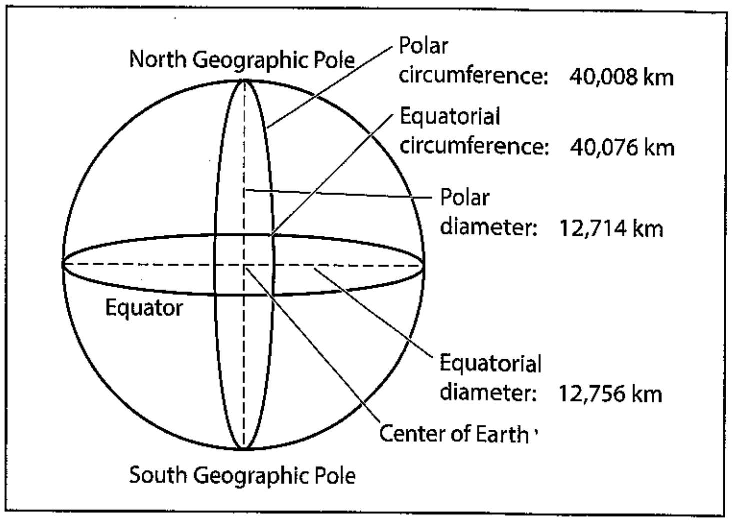


Figure 2-1. Some basic Earth dimensions: The similarities of the polar and equatorial diameters and circumferences indicate that Earth is close to being a perfect sphere. The average diameter of Earth is 12,735 kilometers.

Table 2-1 Comparison of the Spheres of Earth			
Sphere Name	**Density (in g/cm)**	**Phase(s) of Matter**	**Thickness (in km)**
Atmosphere	0.0–0.0001	Gas	600 (approximately)
Hydrosphere	1.0	Liquid	3.8 (average for oceans)
Lithosphere	2.7–3.3	Solid	100
Earth's interior (Geosphere)	2.7–13.1	Mostly solid, some liquid	6378

Outer Spheres of Earth

The region that extends from the outer portion of Earth's interior to where the atmosphere blends into outer space can be considered the outer part of Earth. This portion of Earth is divided into three spheres—atmosphere, hydrosphere, and lithosphere.

Atmosphere The layer of gases that surrounds Earth above the surface of liquid water and rocky material is the **atmosphere.** It is, by volume, composed mostly of the gases nitrogen (78%) and oxygen (21%), but also includes some aerosols—suspended liquids and solids. The atmosphere is the sphere farthest from Earth's center because it is the least dense, and Earth's gravity pulls on it less than on the other spheres. It extends out several hundred kilometers into space, but nearly all of its mass is confined to the few kilometers nearest Earth's surface. The atmosphere is stratified, or layered, into zones—troposphere, stratosphere, mesosphere, and thermosphere—each with its own distinct characteristics such as temperature and composition. The interfaces, or boundaries, of the layers of Earth's atmosphere are called **pauses.** The tropopause, for example, is between the troposphere and stratosphere. (See Selected Properties of Earth's Atmosphere in the *Earth Science Reference Tables.*)

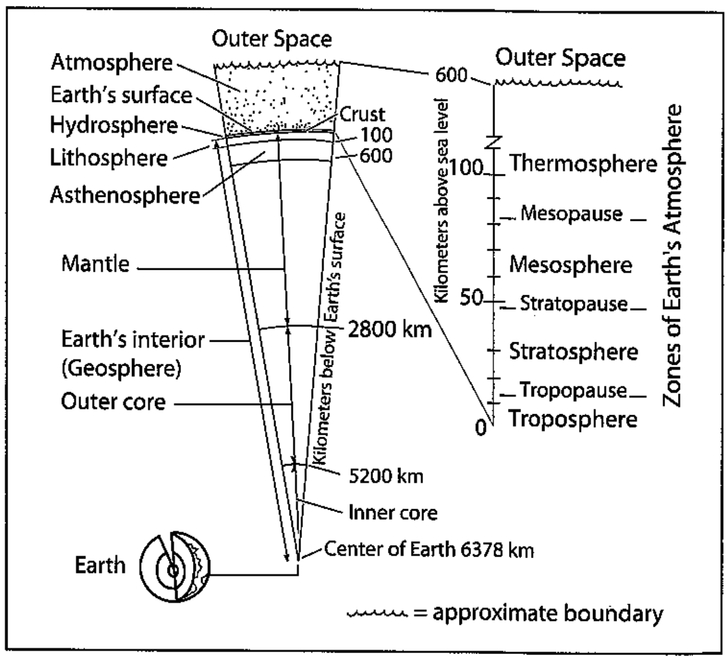


Figure 2-2. A wedge of Earth: The wedge shows the spheres of Earth drawn very close to scale.

Hydrosphere The **hydrosphere** is the layer of liquid water that lies between the atmosphere and much of the upper layer of Earth's interior. The hydrosphere consists of the oceans, which cover about 70 percent of Earth's surface, and other bodies of water such as lakes, streams, and rivers. The hydrosphere is relatively thin, with the oceans averaging only 3.8 kilometers in thickness. The chemical composition of the hydrosphere is mostly liquid H_2O, thus mostly hydrogen and oxygen. Earth's surface waters also contain varying amounts of dissolved gases and dissolved and suspended solids, including life forms.

Lithosphere The layer of rock that forms the solid outer shell at the top of Earth's interior is the **lithosphere.** (See Figure 2-2.) The lithosphere lies directly beneath the atmosphere or the hydrosphere. The lithosphere is approximately 100 kilometers thick and is divided into sections called lithospheric plates. The upper portion of the lithosphere is called the **crust.** Where the crust is not covered by the liquid water (hydrosphere), it is usually covered by a very thin layer of broken-up rocky material. When this material contains abundant organic matter, it is called soil.

Earth's Interior

The region extending from the rocky part of Earth's surface to Earth's center is called **Earth's interior** (geosphere). Many of the features of Earth's interior are shown in the Inferred Properties of Earth's Interior in the *Earth Science Reference Tables.*

Review Questions

1. Which object best represents a true scale model of the shape of Earth?

(1) a table tennis ball (3) an egg
(2) a football (4) a pear

2. Which of the following is NOT evidence that supports Earth's spherical shape?

(1) photographs taken from outer space
(2) ships appearing to sink as they sail past the horizon
(3) the changing seasons
(4) the similarities in gravity at sea level all over Earth

3. In which group are the spheres of Earth listed in order of increasing density?

(1) atmosphere, hydrosphere, lithosphere
(2) hydrosphere, lithosphere, atmosphere
(3) lithosphere, hydrosphere, atmosphere
(4) lithosphere, atmosphere, hydrosphere

4. Which makes up most of Earth's surface?

(1) the atmosphere
(2) the lithosphere
(3) the hydrosphere

5. The lower atmosphere and hydrosphere are bound to Earth by

(1) magnetic fields
(2) atmospheric pressure
(3) the force of gravity
(4) a molecular bonding at the interface

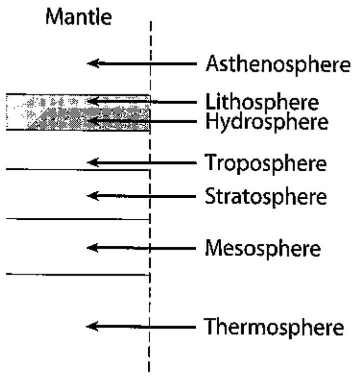
6. What do the tropopause, stratopause, and mesopause all have in common?

(1) Each is a point of maximum temperature in its layer of the atmosphere.
(2) Each is an interface of two layers of the atmosphere.
(3) Each is a region of increasing pressure within the atmosphere.
(4) Each is a zone of decreasing water vapor content within the atmosphere.

7. As depth within Earth's interior increases, the

(1) density, temperature, and pressure decrease
(2) density, temperature, and pressure increase
(3) density and temperature decrease, but pressure increases
(4) density decreases, but temperature and pressure increase

8. The following diagram shows Earth's spheres. Which spheres are zones of Earth's atmosphere?



(Not drawn to scale.)

(1) lithosphere, hydrosphere, and troposphere
(2) stratosphere, mesosphere, and thermosphere
(3) asthenosphere, lithosphere, and hydrosphere
(4) hydrosphere, troposphere, and stratosphere

9. The layer of bedrock near Earth's surface that forms a continuous shell around Earth is called the

(1) troposphere (3) lithosphere
(2) stratosphere (4) hydrosphere

10. Oxygen is the most abundant element by volume in Earth's

(1) inner core (3) hydrosphere
(2) crust (4) troposphere

11. What is the approximate altitude of the mesopause in the atmosphere?

(1) 50 km (2) 66 km (3) 82 km (4) 90 km

12. Which statement most accurately describes Earth's atmosphere?

(1) The atmosphere is layered, with each layer possessing distinct characteristics.
(2) The atmosphere is a mass of gases surrounding most of Earth.
(3) The atmosphere's altitude is less than the depth of the ocean.
(4) The atmosphere is more dense than the hydrosphere, but less dense than the lithosphere.

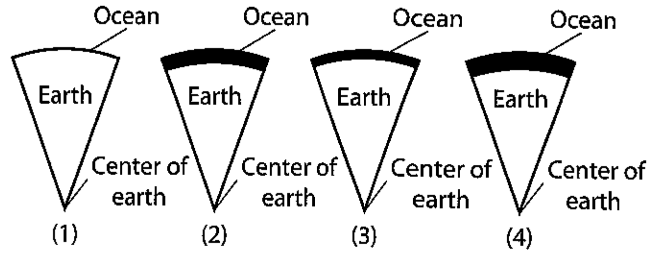
13. Which layer of Earth's atmosphere contains no water vapor, has an atmospheric pressure less than 0.1 atmosphere, and has an air temperature that increases with altitude?

(1) troposphere (3) mesosphere
(2) stratosphere (4) thermosphere

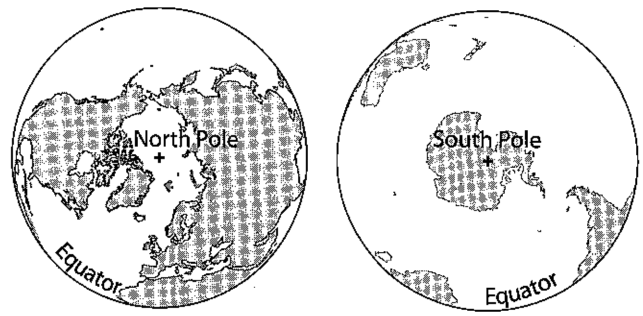
14. The water sphere of Earth is known as the

(1) atmosphere (3) lithosphere
(2) troposphere (4) hydrosphere

15. In the following diagrams, the dark zone at the surface of each wedge-shaped segment of Earth represents average ocean depth. Which segment is drawn most nearly to scale?

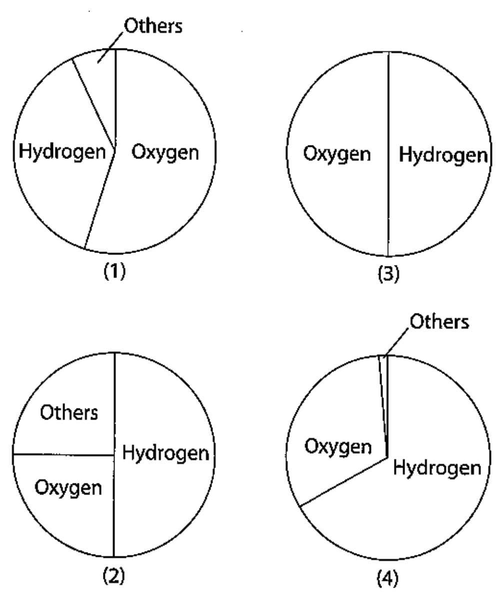


16. The following maps show Earth as viewed from above the North Pole and from above the South Pole. Which statement is best supported by these maps?



(1) Most of Earth's surface is land.
(2) Most of Earth's landmass is in the Southern Hemisphere.
(3) The geographic North Pole is the south magnetic pole.
(4) Most of Earth's surface is hydrosphere.

17. Which graph best represents the percentage by volume of the elements making up Earth's hydrosphere?



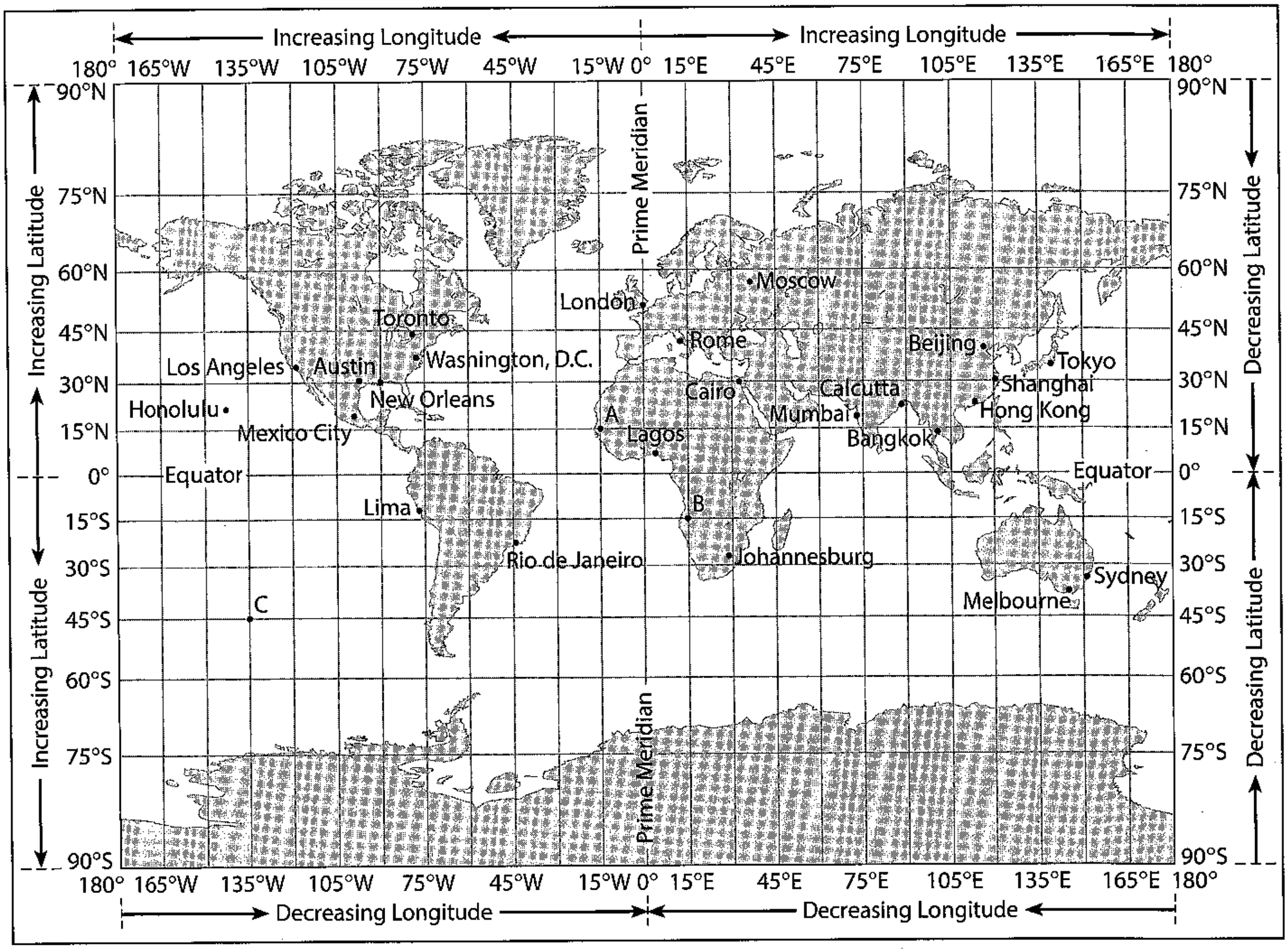


Figure 2-3. World map with latitude-longitude coordinate system

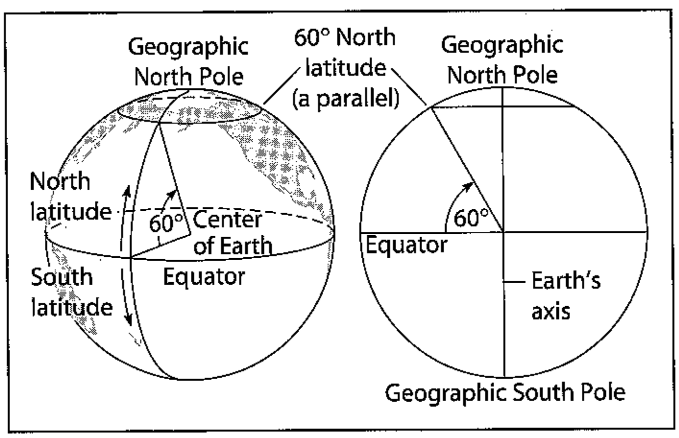


Figure 2-4. The meaning of latitude: Latitude is the angular distance north or south of the equator. On the left, Earth is shown as a sphere with the parallel for 60° N latitude shown as a circle parallel to the equator. On the right, Earth is shown with the north-south axis vertical; the equator and the parallels of latitude then become horizontal lines.

Locating Positions on Earth

To fix the location of a point on any two-dimensional surface such as the surface of Earth, two numbers, called coordinates, are needed. The system for determining the coordinates of a point is called a **coordinate system.** (See Figure 2-3.) The latitude-longitude coordinate system is the one most commonly used to locate points on Earth's surface. Latitude and longitude are measured in angular units: degrees (°) and minutes (′). There are 60 minutes in a degree.

Latitude

The angular distance north or south of the equator is **latitude.** The **equator** marks the middle location on Earth's surface, halfway between the geographic North and South Poles. If a line is drawn from any point on Earth's surface to the center of Earth, the latitude of that point is the number of degrees in the angle between that line and the plane of the equator. All points that have the same latitude lie on a circle that is parallel to the equator. These circles are called parallels of latitude or just parallels. The equator may be considered to be the parallel of latitude 0°. (See Figure 2-4.) As indicated in Figure 2-4, latitude increases north and south of the equator to a maximum of 90° at each pole.

Be sure you understand the meaning of increasing and decreasing latitudes. Increasing latitude means moving away from the equator or towards the geographic poles. Decreasing latitude means moving towards the equator or away from the geographic poles. Remember when writing a location's latitude you must include an "N" for north or an "S" for south, except for the equator, which is just 0° latitude.

Memory Jogger

The geographic North and South Poles are the ends of the axis of Earth's rotation, or spinning.

Measuring Latitude

As shown in Figure 2-5 the altitude of Polaris—the North Star—equals the degree of latitude in the Northern Hemisphere. The altitude of an object in the sky is its angle above the horizon. The latitude of a point on Earth's surface is its angle north or south of the equator. The star Polaris is almost directly over the geographic North Pole of Earth. The altitude of Polaris at any point in the Northern Hemisphere should be the same as the latitude of that point. That is, the altitude of Polaris should change from 0° at the equator to 90° at the geographic North Pole. In the Southern Hemisphere, latitude can be determined by measuring the altitude of certain other stars. To determine the altitude of an object in the sky, an angle-measuring instrument such as a sextant is used.

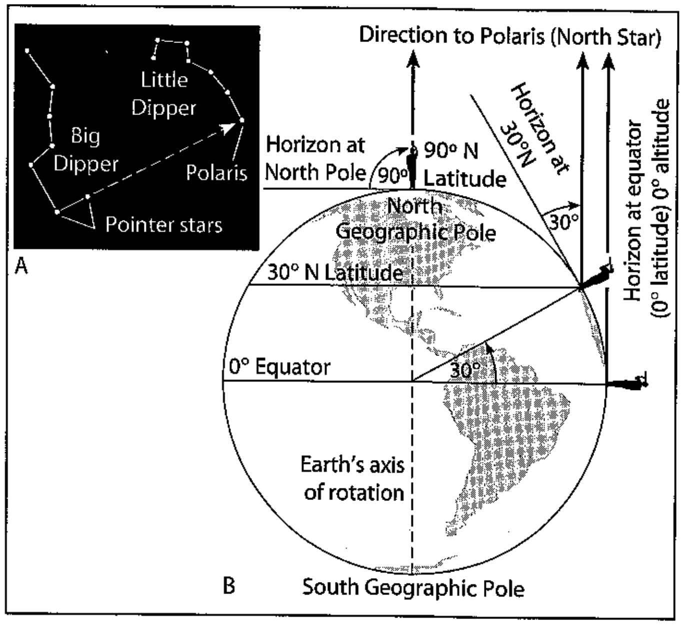


Figure 2-5. Altitude of Polaris equals latitude in the Northern Hemisphere: Diagram A shows the method used to find Polaris, or the North Star, in the night sky. Generally, face north and find the Big Dipper. The Big Dipper is a bright group of stars that is part of the constellation Ursa Major, or Big Bear. Following the pointer stars, move your eye five times the distance that separates the pointer stars. You should easily locate Polaris. The direction toward Polaris is true, or geographic north. The direction toward Polaris is the same for all locations on Earth because Polaris is trillions of miles away. Diagram B shows that the angular altitude of Polaris in the sky equals an observer's latitude in the Northern Hemisphere.

Longitude

As shown in Figure 2-6, **longitude** is an angular distance east or west of the prime meridian. A **meridian of longitude,** or meridian, is any semi-circle on Earth's surface connecting the north and south geographic poles. The meridian that passes through Greenwich, England, has been designated the **prime meridian,** or the meridian of zero longitude. The longitude of any point on the prime meridian is 0°. The longitude of any other point on Earth's surface is the number of degrees between the meridian that passes through that point and the prime meridian. This angle can be measured along the equator or any parallel of latitude. Since a full circle is 360°, longitude increases east or west of the prime meridian from 0° at the prime meridian to 180°. The 180° meridian is the continuation of the prime meridian on the other side of Earth. This meridian somewhat follows the International Date Line.

In writing a location's longitude, be sure to include a west or east direction (80° W longitude; 70° E longitude) except for 0° longitude—the prime meridian—and the 180° meridian. Increasing longitude means going away from the prime meridian or towards the 180° meridian. Decreasing longitude means moving towards the prime meridian or away from the 180° meridian.

Digging Deeper

Greenwich Mean Time can be determined if the observer has an accurate clock that has been set to keep Greenwich Mean Time, or by means of time signals obtained from radio or satellite transmissions that are regularly broadcast.

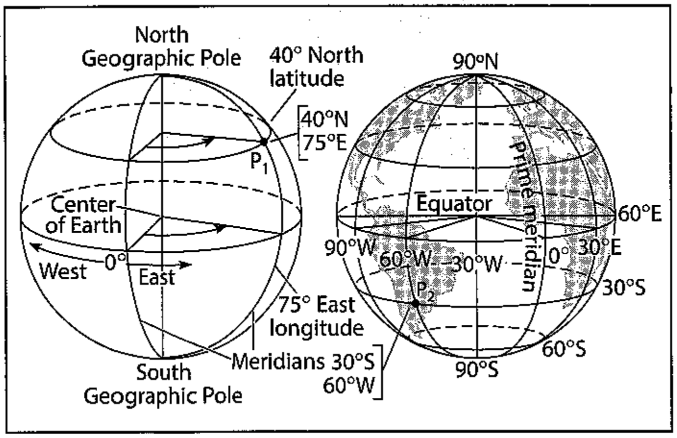


Figure 2-6. The meaning of longitude: Longitude is the angular distance east or west of the prime meridian, which is the meridian passing through Greenwich, England. Latitude and longitude together provide a system of coordinates for locating any point on Earth. The coordinates of point P_1 are 40° N latitude and 75° E longitude. Those for point P_2 are 30° S latitude and 60° W longitude.

Digging Deeper

Find point A on Figure 2-3, and write down the latitude and longitude as accurately as you can. Since this location is right at the intersection of a parallel and meridian, you can be quite accurate. The coordinates for point A are 15° N, 15° W, which is read as "latitude 15 degrees north and longitude 15 degrees west." Try location B. The coordinates are 15° S, 15° E. Location C is 45° S, 135° W. Rio de Janeiro is approximately 23° S, 43° W. Moscow is approximately 56° N, 37° E. Try determining the coordinates of some other locations on Figure 2-3, and check your answers in a world atlas. You can also practice placing locations on a map (such as Figure 2-3) when you know the coordinates. For example, plot 39° N, 77° W on a map. You should be at Washington, D.C. Plot 34° S, 151° E. You should be at Sydney, Australia.

Measuring Longitude

Local noon (12:00) at any point on Earth occurs when a line from the sun to the center of Earth cuts the meridian of that point. At that moment, the sun reaches its highest altitude of the day in the sky. Therefore, the instant of local noon can be determined by observing the sun. Since Earth rotates from west to east at the rate of one rotation per day—360° in 24 hours—it rotates 15° per hour. Therefore, the occurrence of local noon moves from east to west at the same rate of 15° per hour. Longitude can be calculated if, when local noon occurs, the observer knows what time it is at Greenwich, England—or any other location on the prime meridian. For example, if local noon occurs at 1:00 p.m. Greenwich Mean Time (GMT), one hour has passed since the sun crossed the prime meridian; the local longitude is therefore 15° W. Greenwich Mean Time is also called Universal Time. In general, longitude can be calculated by finding the time difference in hours between local sun time and Greenwich Mean Time, and multiplying by 15°. If local time is earlier than Greenwich Mean Time, the longitude is west; if later, it is east.

Using Latitude and Longitude

To read or plot a location on an Earth model such as a map or globe, you need to locate the coordinates for both latitude and longitude and to be able to locate and read the values of the parallels and meridians. Use Figure 2-3 as a typical map with north at the top. The parallels run east and west (right and left). The meridians run north and south (up and down). The values for latitude are at the ends of the parallels on the left and right sides of the map. The values for longitude are at the ends of meridians at the top and bottom of the map. The accuracy of a reading or a plotting of coordinates partly depends upon the size of the map and the spacing of the meridians and parallels.

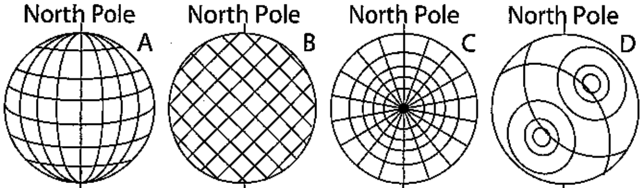
Review Questions

18. Polaris is used as a celestial reference point for Earth's latitude system because Polaris
(1) always rises at sunset and sets at sunrise
(2) is located over Earth's axis of rotation
(3) can be seen from any place on Earth
(4) is a very bright star

19. An airplane takes off from a location at 17°S latitude and flies to a new location 55° due north of its starting point. What latitude has the airplane reached?
(1) 28° N (2) 38° N (3) 55° N (4) 72° N

20. What happens to the altitude of Polaris as you travel northward?

Refer to the following diagrams to answer questions 21 and 22. These diagrams illustrate systems that can be used to determine position on a sphere.



21. Systems of lines such as those illustrated above are called

(1) latitude systems
(2) coordinate systems
(3) great circle systems
(4) axis systems

22. Which of the illustrated systems is most like the latitude-longitude system used on Earth?

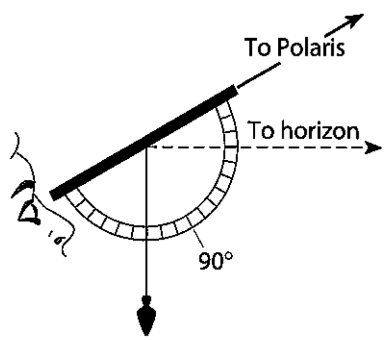
(1) A (2) B (3) C (4) D

---

23. How are latitude and longitude lines drawn on a globe of Earth?

(1) Latitude lines are parallel and longitude lines meet at the poles.
(2) Latitude lines are parallel and longitude lines meet at the equator.
(3) Longitude lines are parallel and latitude lines meet at the poles.
(4) Longitude lines are parallel and latitude lines meet at the equator.

24. In the following diagram, what is the latitude of the observer?

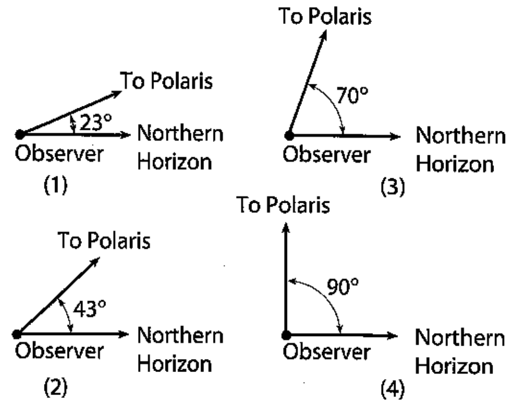


(1) 30° N (2) 60° N (3) 90° N (4) 120° N

25. What is the location of Binghamton, New York?

(1) 42°06′ N, 75°55′ W
(2) 42°06′ S, 76°05′ W
(3) 42°54′ N, 76°05′ W
(4) 42°54′ N, 75°55′ W

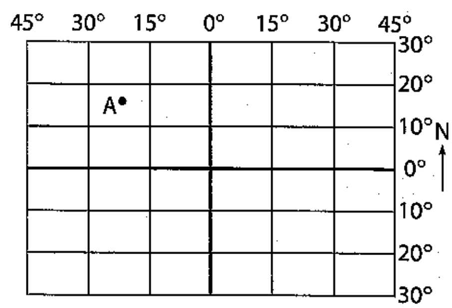
26. Which diagram best shows the altitude of Polaris observed near Buffalo, New York?



27. Which reference line passes through both the geographic North Pole and the geographic South Pole?

(1) 0° latitude
(2) 0° longitude
(3) Tropic of Cancer (23 ½° S)
(4) Tropic of Capricorn (23 ½° N)

28. The following diagram represents a portion of Earth's latitude and longitude system. What are the approximate latitude and longitude of point A?



(1) 15° S 20° W
(2) 15° S 20° E
(3) 15° N 20° W
(4) 15° N 20° E

29. A person knows the sun time on the prime meridian and the local sun time. What determination can be made?

(1) the date
(2) the altitude of Polaris
(3) the longitude at which the person is located
(4) the latitude at which the person is located

30. Which New York landscape region includes the location 43°30′ N, 75°45′ W?

(1) Adirondack Mountains
(2) Erie-Ontario Lowlands
(3) St. Lawrence Lowlands
(4) Tug Hill Plateau

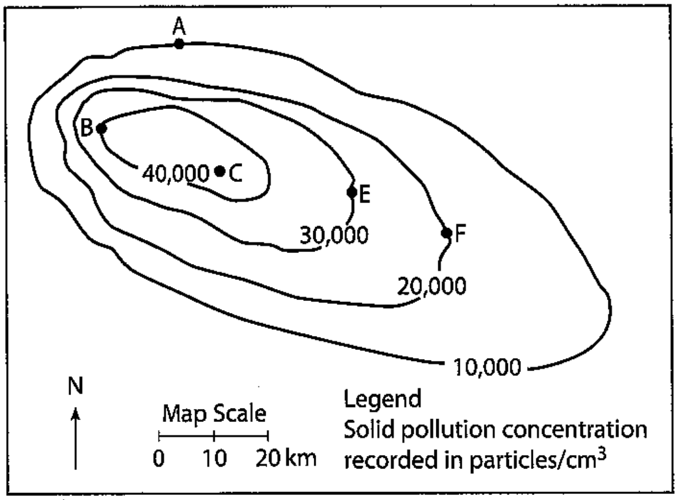


Figure 2-7. Sample field map of solid air pollutants: The data values were measured just above Earth's surface of an area around a coal-fired, electric-generating plant.

Fields

Any region of space or the environment that has some measurable value of a given quantity at every point is a **field.** Thus any aspect of matter or energy that can be measured is a type of field. Examples of field quantities are magnitudes of gravity or magnetism, temperature values, X-ray concentration, sound levels, elevation or depth, atmospheric pressure, wind speeds, acidity of the oceans, and relative humidity.

Isolines

The varying values of a field are often represented on maps by the use of lines that connect points of equal field values—**isolines.** Figure 2-7 is a sample isoline map that has isolines for equal values of the amount of solid pollutants (aerosols) in the air for a portion of Earth's surface. By reading these values of air pollutants, the source of the air pollution could be inferred to be located around area B-C on the map.

Some common examples of isolines are isotherms—which connect points of equal temperature, isobars—which connect points of equal air pressure, and **contour lines**—which connect points of equal elevation.

Gradients and Changes in Fields

Since the environment is constantly changing, field characteristics change with time. This means that any model of a field, such as a weather map, shows the field for only one particular time. The rate of change from place to place within the field is called the **gradient,** or slope.

The gradient can be calculated in two ways. Gradients can be estimated by observing the closeness of the isolines. The closer together the isolines are on a field map, the greater the gradient. On Figure 2-7, you can see that the gradient is large between A and B because the isolines are relatively close. On the other hand, the gradient is small between E and F because the isolines are not as close together for the same amount of horizontal distance as from A to B.

The second method of determining gradient is to calculate it using the following formula:

$$\textbf{gradient} = \frac{\textbf{change in (amount of) field value}}{\textbf{change in distance (horizontal distance)}}$$

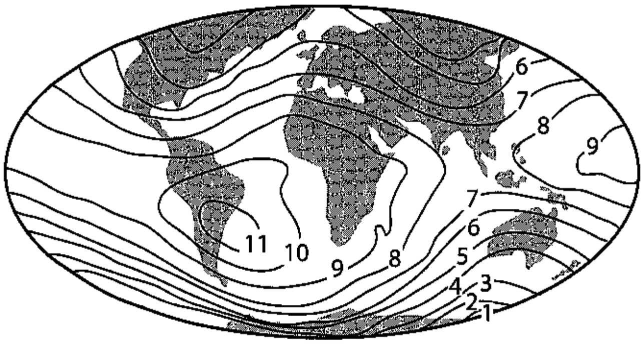
A similar formula is found in the formula section of the *Earth Science Reference Tables.* For example, if a weather map shows a change in temperature of 12°C between two locations that are 3 kilometers apart, the gradient between the two locations is 4°C per kilometer (12°C divided by 3 km).

Digging Deeper

Compute the solid air pollution gradient between locations A and B in Figure 2-7 in number of particles per cm^3 per kilometer. For horizontal distance use the map scale. For the solid pollutant field values, read the isolines and compute the difference between the amount of solid pollutants at A and B. For example: 40,000 particles (B) minus 10,000 particles (A) equals 30,000 particles divided by 20 km equals 1500 particles per cm^3 divided by one kilometer. Compute the same type of gradient from E to F on Figure 2-7. The answer is 500 particles per $cm^3 \div$ kilometer.

Review Questions

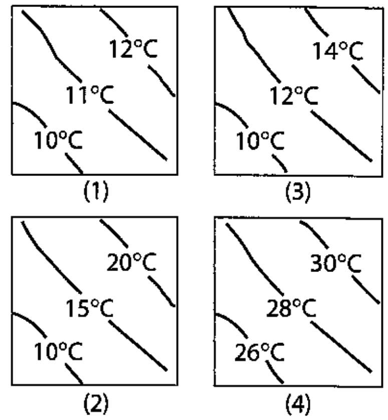
31. The following isoline map shows the variations in the relative strength of Earth's magnetic field from 1 (strong) to 11 (weak).



Which of Earth's plates has the weakest magnetic field strength?
(1) South American plate
(2) African plate
(3) North American plate
(4) Pacific plate

32. As gradient increases, what happens to the distance between isolines?

33. The following four temperature field maps represent the same region on four different occasions. All maps have been drawn to the same scale. Which map shows the greatest temperature field gradient?



34. One thermometer that is held 2 meters above the floor shows a temperature of 30°C. A thermometer on the floor shows a temperature of 24°C. What is the temperature gradient between the two thermometers?
(1) 6°C/m (2) 2°C/m (3) 3°C/m (4) 4°C/m

Mapping Earth's Surface

A map is a model that usually represents a portion or all of Earth's surface on a two-dimensional, or flat, surface. Maps can also model other objects or parts of Earth and the universe.

Topographic Maps

A **topographic map,** or contour map, is a commonly used model of the elevation field of the surface of Earth. The vertical distance or height above or below sea level is **elevation.** What distinguishes topographic maps from other maps is that they use contour lines to model the elevations and shapes of Earth's surface features or landforms. The contour lines are isolines that connect points of equal elevation above—and rarely, below—sea level.

There are many uses for topographic maps including: an aid in hiking or fishing, construction site selection, finding natural resources such as fresh water and trees, and planning highway locations. Topographic maps can also help you find escape routes when natural disasters are predicted.

Reading Contour Lines The difference in elevation between consecutive and different-in-value contour lines is the contour interval. The contour interval is usually listed in the key or legend. If the contour interval is not listed, subtract the difference in the value of two nearby contour lines and divide that number by the number of spaces between the known contour lines. In reading contour lines, pay attention to the following points.

- When contour lines cross a stream, they bend upward toward higher elevations. Contour lines "point" upstream. (See Figure 2-8.)
- When there is a series of consecutively smaller and smaller contour lines, it means that elevation is increasing toward the top of a hill or mountain. (See Paul Hill on Figure 2-8.)
- On most topographic maps, every fourth or fifth contour line—an index contour—is thicker and bolder, and the elevation is shown on that line.
- Often maps show the location of benchmarks with the symbols BM X and an elevation value. The X marks the spot where a metal marker is in the ground labeled with an exact elevation for a location. Figure 2-8 has two benchmarks.
- Depression contour lines are marked with small lines pointing toward the center of a depression. When going uphill on a map, the first depression contour line has the same value as the last regular contour line. Each smaller and smaller depression contour line is one contour interval less than the previous line.

Symbols on Topographic Maps Various types of symbols are used to identify natural and human-made features on topographic maps. There are hundreds of graphic symbols like those shown in the key for Figure 2-8. Most government maps use colors: brown for contour lines to show landform features; red and black for human constructions such as boundaries, roads, and structures; blue for water features; green for woods or areas with trees; and purple where the map has been revised using aerial photographs.

Horizontal Distance on Maps

Contour intervals and contour lines are used to show elevations and depressions. The map scale is used to show distances along Earth's surface. A map scale is a ratio of distance between two places on a map and the actual distance on Earth's surface. Map scales can be expressed in three ways:

- verbally, such as "one inch equals a mile"
- fractionally, such as 1/500,000 or 1:500,000—which means any one unit of distance on the map equals 500,000 of the same units on Earth's surface
- graphically, as shown just below the bottom of the map in Figure 2-8 (This scale is most common.)

To measure the horizontal distance between two places, use a piece of paper with a straight edge. Place this paper on the map, and make a mark on the paper extending it onto the map to mark the beginning location. If it is just a straight-line distance you are trying to measure, then place another mark to match the ending distance on the map. Match up the marks on the piece of paper with the map scale, and read the distance between the two marks. For example, on Figure 2-8, measure the part of Route 84 from the west (left) edge of the map to the eastern (right) edge of the Newburgh River. The answer is 3 miles.

If the horizontal distance to be measured is a curved line, start by putting the straight edge of a piece of paper at the beginning location. Then draw a line on the paper extending it onto the map to mark the beginning spot. Repeat this each time you come to a significant bend on the map. Keep twisting the piece of paper and drawing lines until you come to the end of

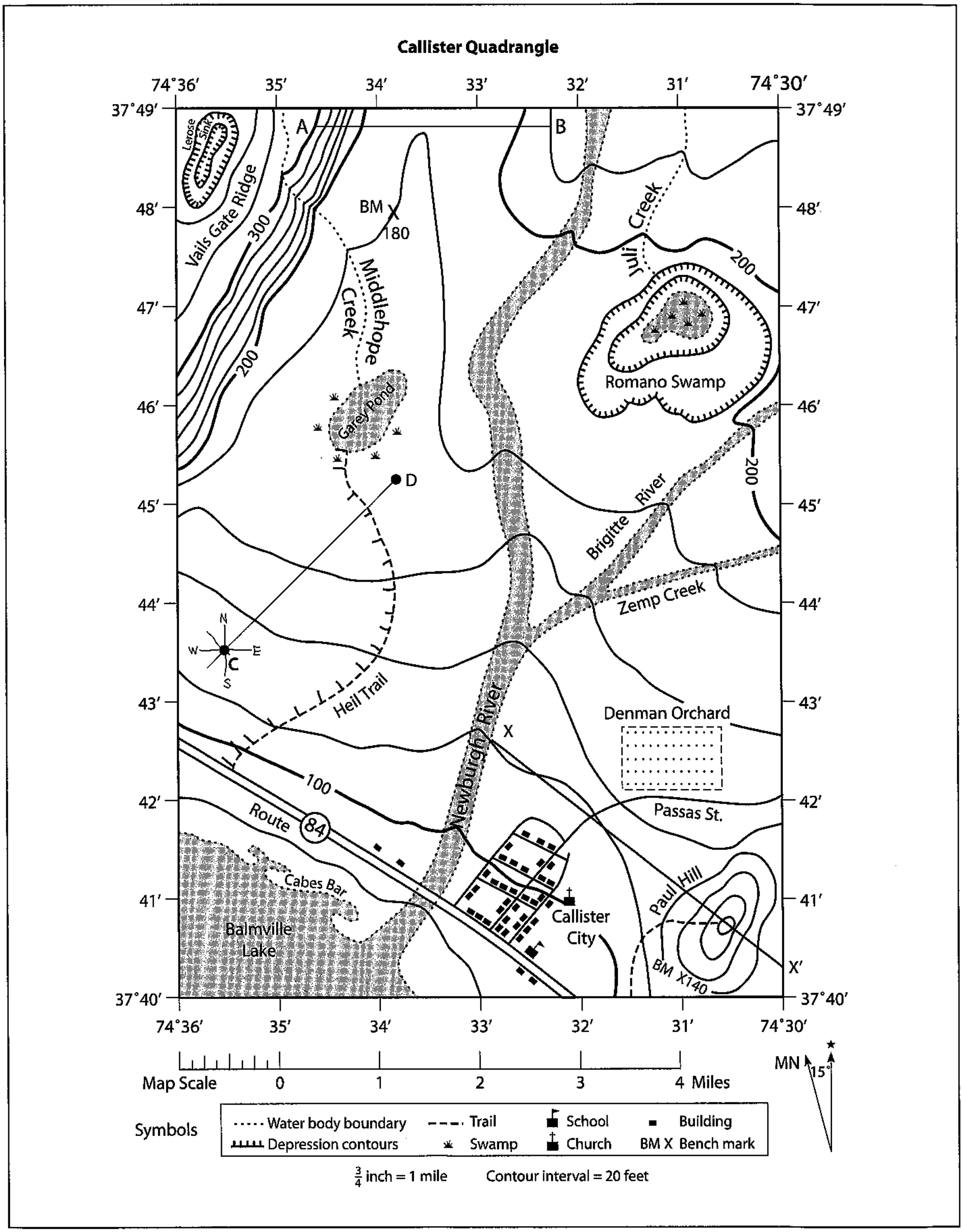


Figure 2-8. A sample topographic (contour) map

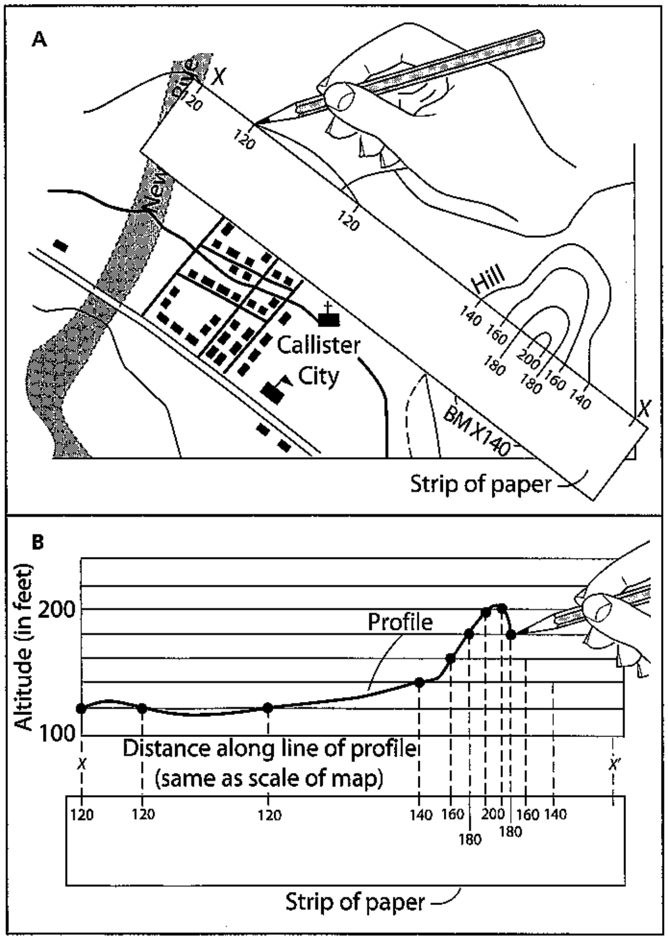


Figure 2-9. Constructing a profile along the line X-X′ on the contour map of figure 2-8: In drawing A, the edge of a strip of paper is placed along the line, and a mark is made wherever the paper crosses a contour line. The marks are labeled with the corresponding altitude. The marks are then projected upward to locate dots on a piece of lined paper as in drawing B. Finally the dots are connected with a smooth curved line, and the profile is complete.

the distance to be measured. Compare the total length of the marks on the piece of paper with the map scale and measure the distance. On Figure 2-8, Heil Trail from Route 84 to Garey Pond shows the marks made to measure its distance. The length of the Heil Trail is approximately 4 miles.

Topographic Map Gradient and Profile

Gradient, or slope, on topographic maps seems unusual because you are dealing with two distances. The field value is a vertical distance, or elevation, and the other value is the horizontal distance along Earth's surface. For practice, compute the gradient—in feet per mile—of the Newburgh River in Figure 2-8 from the 180-foot contour line to the 100-foot contour line. Your result should be approximately 21 feet per mile. On any map of the elevation field, the relative amount of gradient can be estimated using the distance between the isolines. The more closely spaced the lines, the steeper the gradient. In the map example, the gradient is steep just to the east of Vails Gate Ridge, so the contour lines are close together. In the area around the Denman Orchard, the gradient is gentle, so the contour lines are far apart.

A topographic map represents three dimensions—length, width, and height, or elevation. A single contour is two-dimensional, but a series of contours shows the third dimension. A **profile** is the side view of an area's landscape. This model uses upward and downward changes of a line to show changes in elevation and slope. Drawing a profile can show the three-dimensional nature and the gradient of a field. The method for making a profile of a contour map is illustrated in Figure 2-9. The profile is drawn for the region between X and X′ in the southeast corner of the map in Figure 2-8.

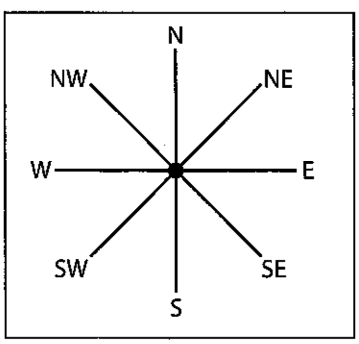


Figure 2-10. A sample compass rose: Compass roses are used to determine directions on maps and in many cases give geographic directions and not magnetic, or compass directions—which are usually different. Directions are often determined to the accuracy of the eight cardinal directions shown here.

Map Direction

Maps are usually constructed so that the top of the map is north, the bottom is south, the right side is east, and the left side is west. Most maps, including topographic maps, usually show directions by indicating geographic north with some type of arrow. Geographic north is the direction to Earth's geographic North Pole. The map in Figure 2-8 indicates geographic north by ★. An MN on the map indicates the direction of magnetic north. Often, instead of a north arrow, a map will have a compass rose, such as the one in Figure 2-10. To find the direction from one location to another, draw a simple compass rose on the location from which you are determining the direction. Then draw a straight line to the other location. The straight line crosses the compass rose at the correct direction. This method is illustrated in Figure 2-8 from point C to point D where the compass direction of D from C is northeast. Compass directions are usually given to the nearest of the eight cardinal directions shown on the compass rose in Figure 2-10.

Review Questions

Base your answers to questions 35 through 44 on the map in Figure 2-8.

35. What is the maximum altitude of Denman Orchard?

(1) 140 feet
(2) 150 feet
(3) 159 feet
(4) 161 feet

36. What is the longitude of the middle of Romano Swamp?

(1) 37°47′ North
(2) 37°47′ West
(3) 74°31′ North
(4) 74°31′ West

37. What is the distance from Passas Street at the margin of the map to where it meets Route 84?

(1) $2\frac{1}{2}$ miles
(2) 3 miles
(3) $3\frac{1}{2}$ miles
(4) 4 miles

38. What is the gradient of the Brigitte River from the 200-foot contour line to the contour line before the Brigitte River meets the Newburgh River?

(1) 5 to 10 feet/mile
(2) 15 to 20 feet/mile
(3) 25 to 30 feet/mile
(4) 35 to 40 feet/mile

39. What is the latitude of the church?

(1) 74°32′ North
(2) 74°32′ West
(3) 37°41′ West
(4) 37°41′ North

40. Where is the steepest slope located on the map?

41. The biggest area of gentle slopes is found in the vicinity of

(1) Garey Pond
(2) Denman Orchard
(3) Paul Hill
(4) Zemp Creek

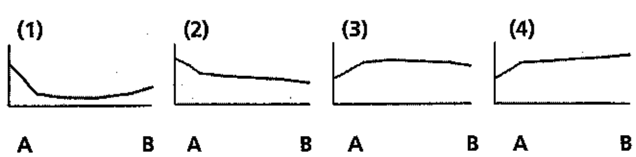
42. Which direction is Vails Gate Ridge from Callister City?

(1) north
(2) northwest
(3) northeast
(4) west

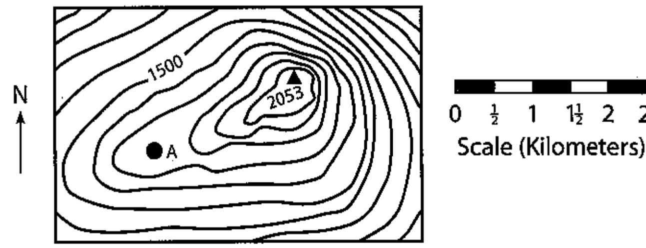
43. Toward what direction is the Brigitte River flowing?

(1) south
(2) southwest
(3) north
(4) northeast

44. Which of the following profiles represents the shape of the landscape between A and B on the map?



45. On the following topographic map, what is the most likely elevation of point A?

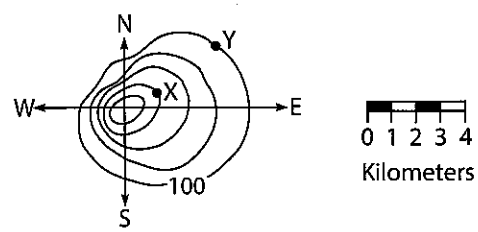


(1) 1250 m
(2) 1650 m
(3) 1750 m
(4) 1850 m

46. What is the approximate straight-line distance from Mt. Marcy in the Adirondacks to Slide Mountain in the Catskills?

(1) 120 km
(2) 150 km
(3) 205 km
(4) 235 km

Base your answers to questions 47 and 48 on the following diagram, which represents a topographic map of a hill.



Contour interval=10 meters

47. On which side of the hill does the land have the steepest slope?

(1) east
(2) south
(3) northeast
(4) northwest

48. What is the approximate gradient of the hill between points X and Y?

(1) 1 m/km
(2) 10 m/km
(3) 3 m/km
(4) m/km

Practice Questions

Directions

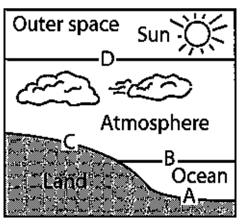
Review the Test-Taking Strategies section of this book. Then answer the following questions. Read each question carefully and answer with a correct choice or response.

Part A

1 The latitude of an observer on Earth's surface can be determined by measuring the altitude of Polaris because Earth has a

(1) nearly spherical shape
(2) nearly circular orbit around the sun
(3) variable length of day
(4) fairly constant period of revolution

2 Which line best identifies the interface of the lithosphere and the troposphere?



(Not to scale.)

(1) A (2) B (3) C (4) D

3 The following data table shows the altitude of Polaris as recorded by four observers at different locations on Earth.

Observer	Altitude of Polaris
A	90°
B	30°
C	30°
D	20°

Which statement is best supported by the information in the table?

(1) Observer A was at the equator.
(2) Observers A and B measured the altitude during daytime hours.
(3) Observers B and C measured the altitude at the same latitude.
(4) Observers B, C, and D were in the Southern Hemisphere.

4 Which latitude and longitude coordinates represent a location on the continent of Australia?

(1) 20° N, 135° E
(2) 20° N, 135° W
(3) 20° S, 135° E
(4) 20° S, 135° W

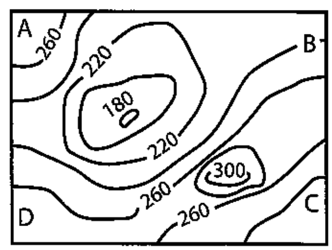
5 Which statement is true about an isoline on an air temperature field map?

(1) It represents an interface of high and low barometric pressures.
(2) It indicates the direction of maximum insolation.
(3) It increases in magnitude as it bends southward.
(4) It connects points of equal air temperature.

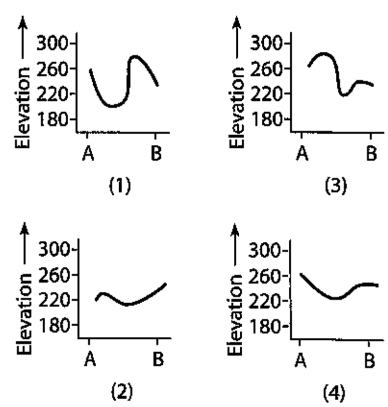
6 Which of the following items is a model?

(1) a globe
(2) a ruler
(3) a hand lens
(4) a mineral specimen

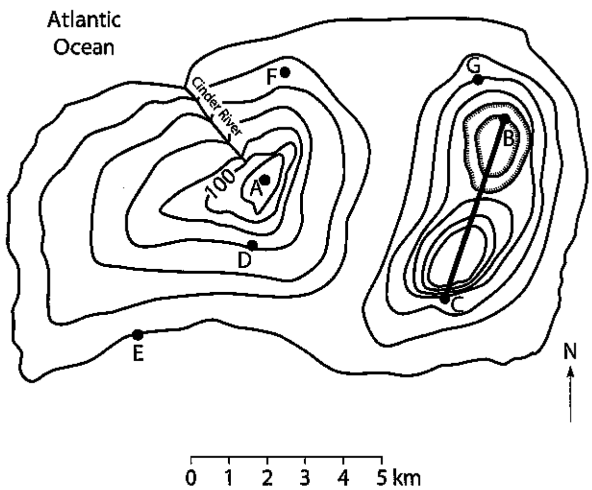
7 The following map represents an elevation field.



Which graph best represents the elevation profile along a straight line from point A to point B?



Base your answers to questions 8 through 12 on the following topographic map of an island. Points A through G represent locations on the island. Elevations are in meters.



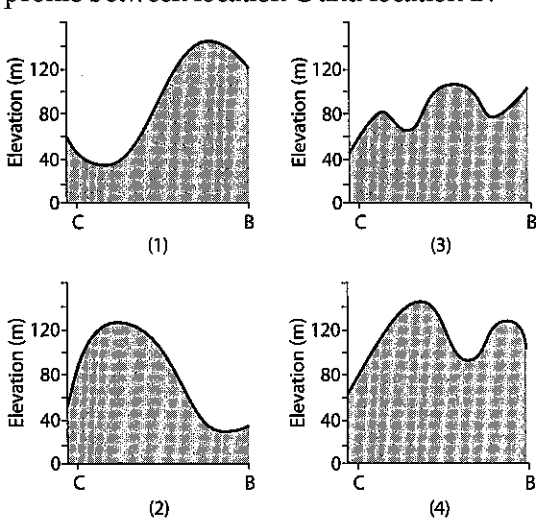
8 Which point is located on the steepest slope?
(1) F (2) B (3) C (4) D

9 In which direction does the Cinder River flow?
(1) southeast (3) northeast
(2) southwest (4) northwest

10 What is the contour interval for this map?
(1) 10 m (2) 15 m (3) 20 m (4) 25 m

11 Which two points have the same elevation?
(1) G and F (3) C and D
(2) B and D (4) G and C

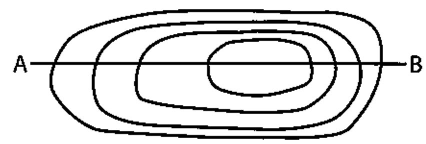
12 Which diagram best represents the topographic profile between location C and location B?



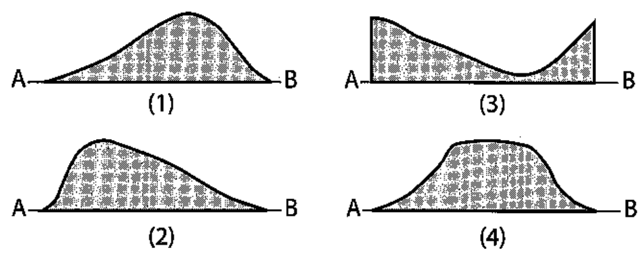
13 A movement of volcanic ash occurred at an altitude of 1.5 kilometers. In which layer of Earth's atmosphere did the ash cloud travel?
(1) troposphere (3) mesosphere
(2) stratosphere (4) thermosphere

14 What is the distance in degrees east or west of the prime meridian called?
(1) longitude (3) equator
(2) latitude (4) altitude

15 The following diagram represents contour lines on a topographic map with cross-section line AB.

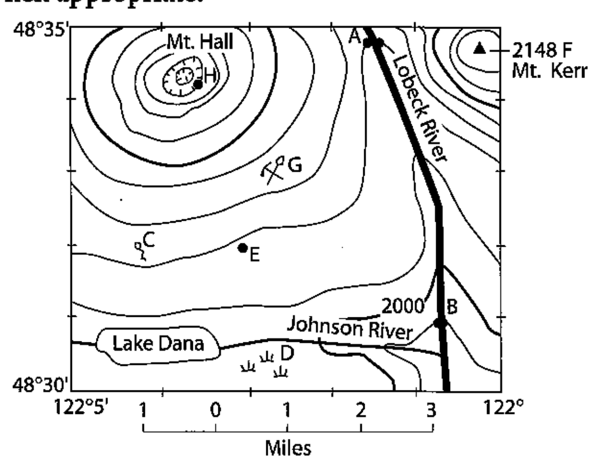


Which diagram best represents the topographic profile along line AB?



Part B

The following topographic map shows a portion of an area of inactive volcanoes in the United States. The contour interval is 20 feet. Base your answers to questions 16 through 20 on this diagram. REMEMBER: State directions or units of measure when appropriate.



16 What is the latitude of point E to the nearest minute? [2]

17 What is the longitude of point E to the nearest minute? [2]

18 In which direction does Johnson River generally flow? [1]

19 What is the elevation of point H on the rim of the crater of Mt. Hall in feet? [1]

20 What is the distance along Lobeck River from point A to point B to the nearest quarter-mile? [1]

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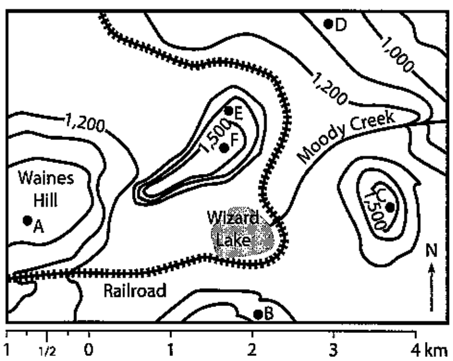
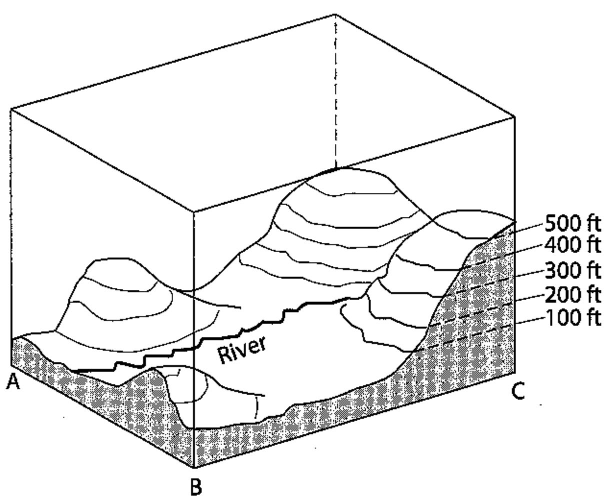
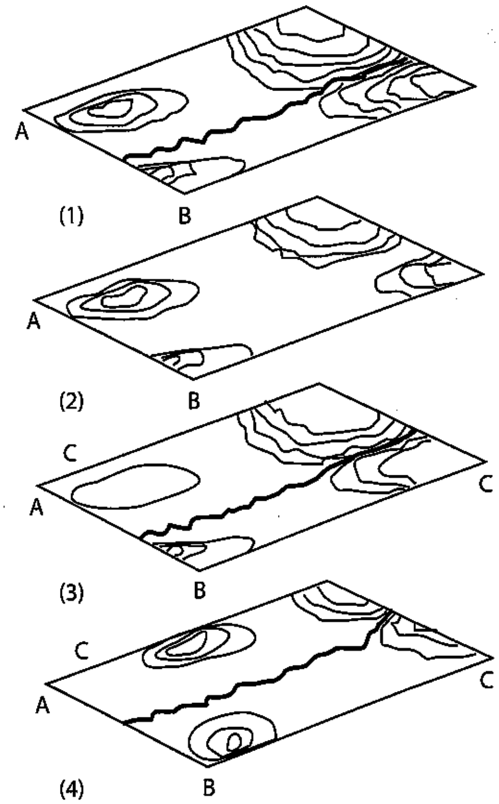
21 The following is a topographic map.



What is the approximate length in kilometers of the railroad tracks shown on the map ? [1]

22 The following diagram shows a three-dimensional model of a landscape region.

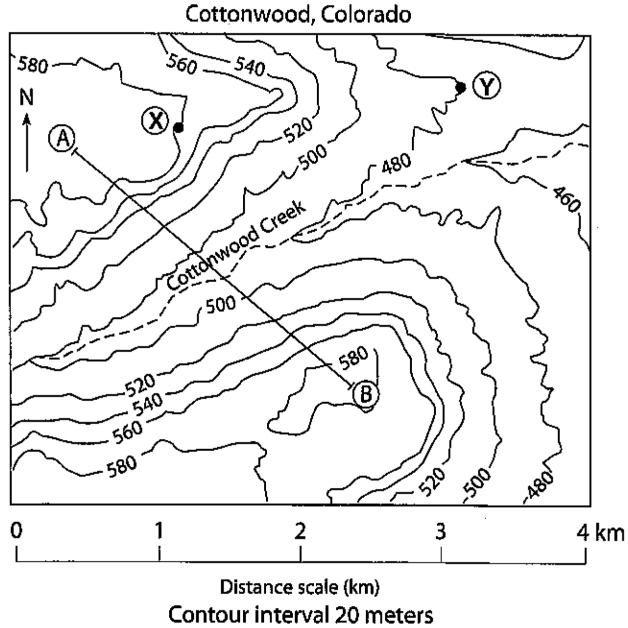




Which map view best represents the topography of this region? [1]

Base your answers to questions 23 through 26 on the following topographic map of Cottonwood, Colorado. Points A, B, X, and Y are marked for reference.

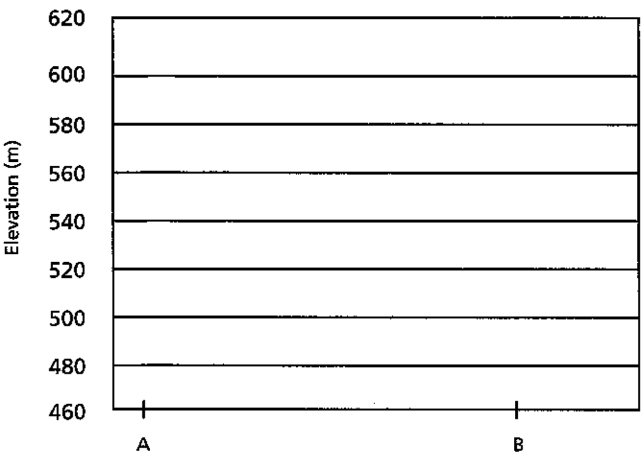
Cottonwood, Colorado



23 State the general direction in which Cottonwood Creek flows. [1]

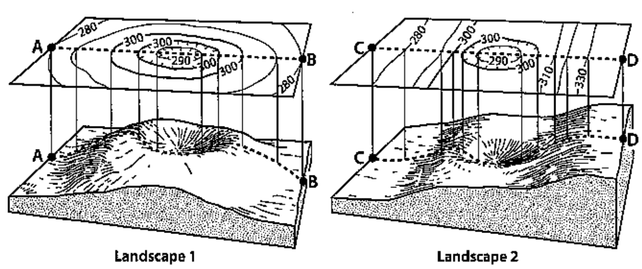
24 State the highest possible elevation, to the nearest meter, for point B on the topographic map. [1]

25 On the following grid, draw a profile of the topography along line AB shown on the map. [2]



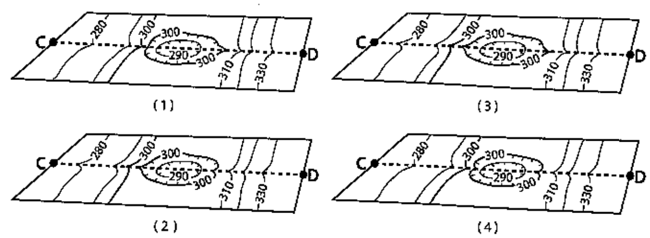
26 Use the following directions to calculate the gradient of the slope between points X and Y on the topographic map.
(a) Write the equation for gradient. [1]
(b) Substitute data from the map into the equation. [1]
(c) Calculate the gradient and label it with the proper units. [1]

Base your answers to questions 27 and 28 on the topographic maps and block diagrams of two landscape regions shown below. The block diagrams show a three-dimensional view of the topographic maps directly above them. Elevations are measured in feet. Points *A*, *B*, *C*, and *D* are locations on Earth's surface.

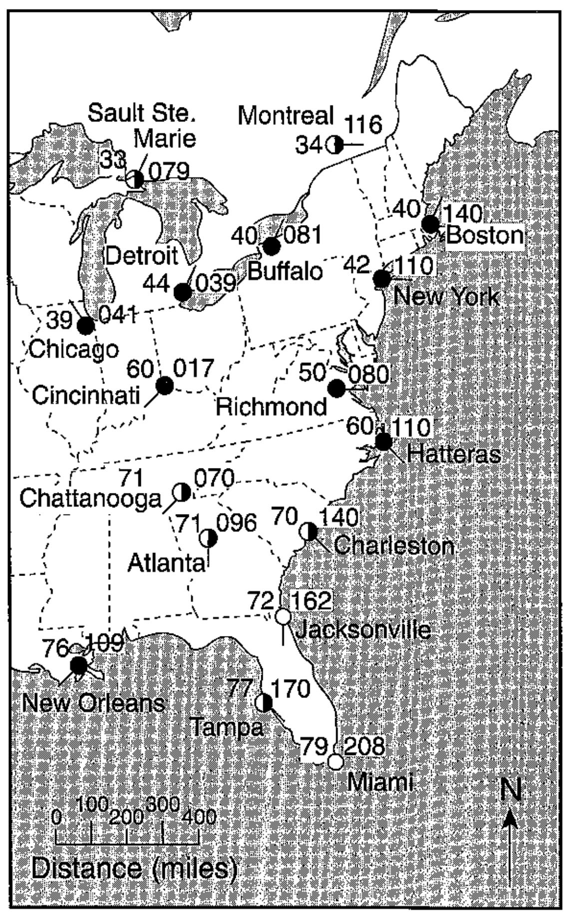


27 Which contour interval is used on both topographic maps?
(1) 10 ft
(2) 20 ft
(3) 30 ft
(4) 40 ft

28 A stream begins to flow downhill from point *D* toward the depression. After a period of time, the depression fills with water. Overflowing water from the depression moves downhill toward point C. Which topographic map shows the most likely resulting change in the contour lines?



Base your answers to questions 29 through 32 on the weather map provided below which shows partial weather station data for several cities in eastern North America.



29 On the weather map provided, draw isotherms every 10°F, starting with 40°F and ending with 70°F. Isotherms must extend to the edges of the map. [2]

30 Calculate the temperature gradient between Richmond, Virginia, and Hatteras, North Carolina, by following the directions below.

(a) Write the equation for gradient.
(b) Substitute data from the map into the equation. [1]
(c) Calculate the average gradient and label your answer with the correct units. [1]

31 In which city is the temperature gradient the smallest?
(1) Cincinnati
(2) New Orleans
(3) Richmond
(4) Detroit

32 State the general relationship between air temperature and latitude for locations shown on the map. [1]

Part C

The planet in the following paragraph is fictional. Use the information in the paragraph and your knowledge of earth science to answer questions 33 through 38.

Glick is a planet in a solar system very similar to our own. Planet Glick is very similar to Earth except for the following differences. Glick's axis of rotation has no tilt. It rotates from east to west, approximately twice as fast as Earth. Zelda is a star that is visible directly over Glick's South Pole and Glotch is a star visible directly over Glick's North Pole. A latitude-longitude system such as that on Earth has been established for Glick.

33 Why would a plastic relief replica of a continent on Glick be considered a model? [1]

34 If planet Glick has a hydrosphere, what two chemical elements is it primarily composed of? [1]

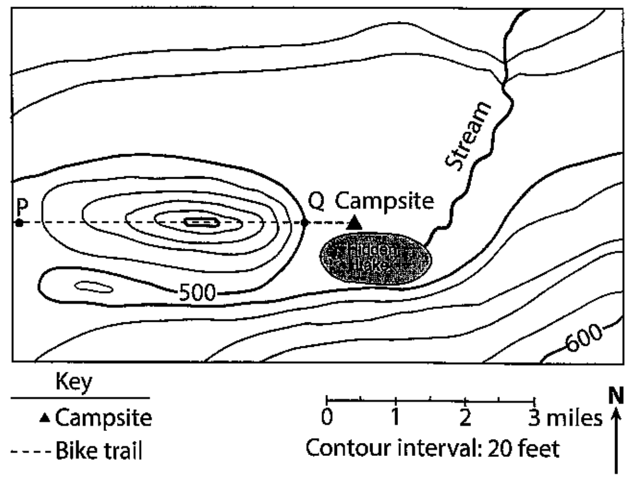
35 In relationship to Glick's atmosphere and lithosphere, what would be the relative location of its hydrosphere? [1]

36 Where would a majority of Glick's most dense substances be located in the planet? [1]

37 At a certain location on Glick, the star Zelda is observed at 37° above the horizon. From this information, what conclusion can you draw about the latitude and longitude of this location? [2]

38 If you traveled due west in the northern hemisphere of Glick at night, what changes might you observe in the altitude of the star Glotch? [1]

Base your answers to questions 39 through 42 on the topographic map below. The map shows a location where a series of students went camping using mountain bicycles on July 1, 2003.



39 State the evidence shown on the map that indicates that the area directly north of Hidden Lake is relatively flat. [1]

40a State the general compass direction in which the stream is flowing. [1]

40b State how the contour lines provide the evidence for determining this direction. [1]

41 On July 2, 2003 the students decided to move their campsite 1 mile directly east of their original campsite that is located on the map above. On the map above place another campsite symbol to indicate the location of the July 2 campsite. [1]

42 The students decided to take a route home to avoid riding their bicycles up the steep hill. Plan a route that will take the campers back to point P from their July 2 campsite that will involve the least change in elevation. On the map above draw a line that shows this route. Place arrows on the route line to show the direction that the students will be traveling. [1]