



Seeing the Third Dimension

Life Skills:

- Thinking & Reasoning
- Communication

Time Frame:

90 minutes (2 class periods) to complete all 4 exercises

Group Size:

Individual students or teams

Summary:

This activity uses a variety of topographic map exercises to emphasize how these maps accurately represent a third dimension, elevation.

National Science Education Standards:

Social Studies Content Standard IIIb. People, Places, and Environments: Create, interpret, use, and distinguish various representations of the Earth, such as maps, globes and photographs.

Main Curriculum Tie:

Idaho Geography of Western Hemisphere 2.1.1- Explain and use the components of maps.

Utah Geography for Life 1.1.b- Examine characteristics of maps.

Wyoming Social Studies 5.1- Students use charts, maps and graphs.

Intended Learning Outcomes:

- Use science processes and thinking skills.
- Demonstrate understanding of concepts, principles and systems.
- Communicate effectively using scientific language and reasoning.

Materials:

- Simplified topographic map
- Topographic profile sheet
- Ruler
- Crayons, colored pencils or markers

Background For Teachers

Topographic maps are different from all other maps with the exception of shaded-relief maps in that they provide a third dimension, elevation. The difference between topographic and shaded relief maps is that the former are generally larger scale (represent smaller areas in greater detail) and use contour lines rather than different colors to more accurately represent changes in elevation.

Topographic maps employ seven colors: black, blue, brown, green, pink, purple and red. Black represents man-made objects like buildings, roads and trails. Blue indicates bodies of water such as oceans, lakes, rivers and wetlands. Contour lines are the only feature represented in brown. Green signifies vegetation. Urban areas are shaded in pink. Purple identifies updated map features that have not been ground-truthed (surveyed in). Major highways are rendered in red.

A topographic map legend, found in its lower margin, includes a variety of scales (bar, verbal, and ratio or fractional) used for calculating horizontal distances. A bar scale and compass allow a quick determination of the distance between two points provided the range of the compass or length of the bar scale is not exceeded. In that case, a verbal scale and ruler prove useful. For example, if the verbal scale is 1 inch = 2000 feet, and the measured distance between two points on the map is 6 1/2 inches, then the actual distance is 6.5x2000 or 13,000 feet. In the absence of a verbal scale, the ratio scale can be converted to one. A ratio (fractional) scale or 1:24,000 (1/24,000) simply means that one map inch equals 24,000 actual inches, therefore dividing 24,000 by 12 yields a verbal scale of 1 inch = 2000 feet.

The map legend also serves up north in three flavors: true, grid and magnetic. True north refers to the geographic north pole and is marked in the northern hemisphere night sky by *Polaris*, the north star. Grid north is a function of the survey datum and the universal transverse mercator map projection used to produce the map. Magnetic north is the direction a compass points, and rarely coincides with the geographic north pole. Topographic maps are always oriented so true north is at the top. This means the left margin is west, the right east and the bottom south.

The variation between true (geographic) north and magnetic north is called the magnetic declination, and can be used to adjust a compass so it points toward true north. The magnetic declination is given in degrees (°) and minutes (′) east (E) or west (W) of true north. The magnetic declination changes over time. For example, as of January 10, 2008 the magnetic declination at Kemmerer, WY was 12° 13′ E and changing at a rate of 0° 8′ W annually.

The legend also includes one other very important piece of information, the contour interval. This is the vertical distance between two successive contour lines and is critical to understanding the third dimension, elevation.

Topographic maps are overlaid with UTM (universal transverse mercator) grid lines, and have latitude and longitude hashmarks. Latitude hashmarks are found in the left and right map margins, longitude hashmarks on the top and bottom map margins. Both UTM grid lines, and latitude and longitude are useful position keeping tools.

The following are simple rules for interpreting topographic maps:

1. Contour lines are the only features reproduced in brown on topographic maps. They show elevation (height above or below sea level). Each contour line represents a single elevation.
2. Contour lines never cross each other.
3. The area inside a closed contour line is higher in elevation (uphill) and the area outside is lower in elevation (downhill).
4. Every fifth contour line, known as an *index contour*, is darker and wider, and labeled with its elevation.
5. The more closely spaced the contour lines, the steeper the terrain is.
6. The *Rule of Vs* states that where contour lines cross streams they are bent to form a V shape, and the sharp end of the V points uphill (Figure 1).
7. The *Rule of O's* states that adjacent contour lines forming a series of roughly concentric circles of decreasing diameter represent hilltops or mountain peaks. Often an X in the interior of the smallest circle indicates the highest point and its elevation is given (Figure 2).
8. *Depressions* look similar to hilltops except short tic marks called hachures are placed perpendicular to the inside edge of the contour line and point downhill (Figure 3).

A student handout with these simple rules and the associated figures reproduced here in the left margin is provided on page 7. The following are answers to questions posed in figures 1-3 of the student handout:

The diagram below shows Figure 1 with its index contours labeled. Given a contour interval of 20 feet, by definition the interval between index contours is 100 feet. Given the *Rule of Vs*, the index contours to the right of the 7200 index contour are downstream so they are at lower elevations, and the ones to the right must therefore be uphill.

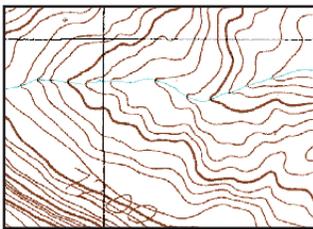


Figure 1—Shows a stream (blue) about which the contour lines (brown) are bent to form Vs. The tip of the V points uphill.

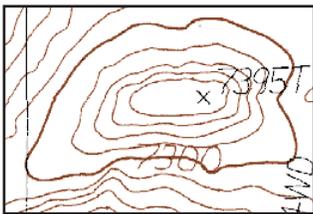


Figure 2—Shows a hilltop with the highest point marked with an X and its elevation.

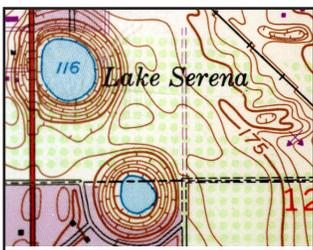
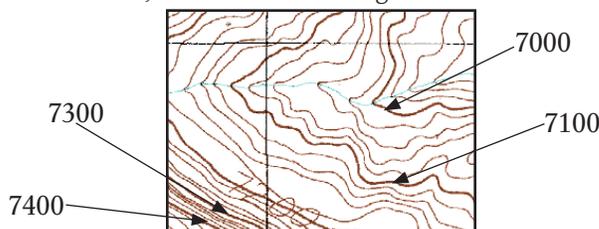


Figure 3—Shows a group of depressions (sinkholes) with hachures perpendicular to contour lines and pointing downslope.



In Figure 2 the index contour is labeled 7300 and the highest point is labeled 7395, a difference of 95 feet. There are four contour lines between the labeled index contour and the highest point for a total of 5 intervals between known elevations. 95 divided by 5 equals 19. Given the fifth contour line is missing, the contour interval must be larger than 19, therefore it is determined to be 20 feet.

In Figure 3 the index contour labeled 175 is uphill from the depression (sinkhole) in the upper left with a labeled elevation of 116, a difference of 59 feet. There are two unlabeled index contours plus one additional contour line and the water level in the depression for a total of 12 intervals between the known elevations. 59 divided by 12 equals 4.9167. Given the twelfth contour line is missing, the contour interval must be larger than 4.9167, therefore it is determined to be 5 feet.

Instructional Procedures

Topographic maps are an essential tool employed by earth scientists. Students will benefit from understanding how to use them. They are often already adept in their use of other types of maps, but encounter difficulty with topographic maps because they present a third dimension (elevation) using contour lines. These exercises are designed to help students conceptualize and visualize how contour lines represent changes in elevation on a map. They are meant to supplement a lesson that has presented topographic maps as outlined in the background section.

Exercise 1—Elevation Model

Provide each student with a copy of the *simplified topographic map* (See page 8). Instruct them to color each 100 foot interval between consecutive contour lines a different color. Suggest they adopt a color scheme that transitions from darker (or cooler) to lighter (or warmer) colors to enhance the 3-D effect of the shading. This will transform it from a topographic map to a shaded relief map improving their ability to visualize how elevation is represented by the contour lines on a topographic map. Have them produce an elevation key for their color scheme in the margin. The elevation of each contour line can be determined from labeled elevations given on the map. This exercise can be started in class and finished as a homework assignment. See examples of completed maps on page 9.

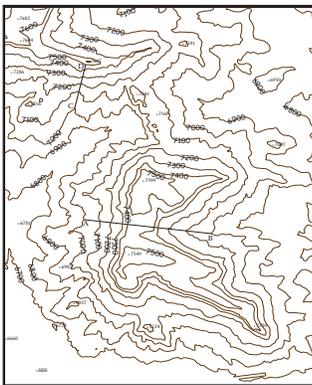


Figure 4—Step 1. Label contour lines.

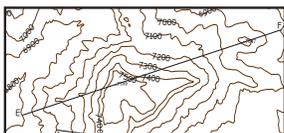


Figure 5—Step 2. Draw a straight line 5-8½ inches in length and passing through two points of known elevation. Label the start point E and the end point F. Begin and end the line on a contour line.

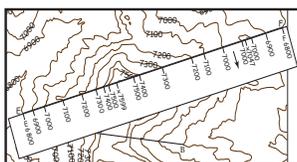


Figure 6—Step 3. Align a strip of paper with your line and make a tic mark for each contour line and labeled elevation between points E and F. Label each tic mark with its elevation.

Exercise 2—Topographic Profile

Provide each student with a copy of the *simplified topographic map* (See page 8) and a *topographic profile sheet* (See page 10). If the students completed Exercise 1 they can use the *simplified topographic map* that was previously provided. This exercise should be conducted as an in-class demonstration, but students should follow along and complete their own independent topographic profile. Figures 4-8 that appear in the left margin are reproduced on pages 11 and 12.

Instruct students to:

1. Label each contour line on the *simplified topographic map* with the correct elevation. The contour line elevations can be determined from the labeled elevations (Xs on the map). For example, near the center of the map the labeled elevation is 7599 feet. Therefore students should mark the next contour line below it 7500, the one below that 7400 and so on. The contour lines will range in elevation from 6700 to 7600 (see Figure 4).
2. Use a ruler to draw a straight line of your choosing 5-8½ inches in length that passes through two points with labeled elevations, and begins and ends on a contour line. Label the start point E and the end point F (See Figure 5).
3. Use a strip on paper approximately 8½ inches in length and 1 inch in width to mark the location of points E and F, the two labeled elevations and each contour line crossed. Label each mark on the paper strip with its elevation. If your line crosses the same elevation contour consecutively determine whether the elevation between them is increasing or decreasing, and place an up arrow (increasing) or down arrow (decreasing) between those marks on the paper strip (See Figure 6).

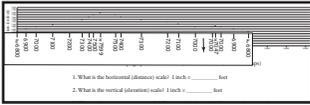


Figure 7—Steps 4-7. Place a small dot at the appropriate elevation on the profile sheet for each tic mark on the paper strip.

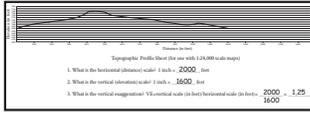


Figure 8—Step 8. Draw a smooth line through the dots to create a topographic profile.

4. To transfer the information from the paper strip to the *topographic profile sheet* keep point E aligned with the vertical line (y-axis) and keep the edge of paper strip parallel to the horizontal lines of elevation.
5. Align the marked edge of the paper strip with the line of elevation on the *topographic profile sheet* that is equal to Point E's elevation. Now place a small dot on the y-axis to represent point E (See Figure 7). Place other small dots on the profile sheet for any other marks on the paper strip that have the same elevation as Point E.
6. Now move the marked edge of the paper strip up (or down) to the next line of elevation on the *topographic profile sheet*. Make sure that point E on the paper strip is still aligned with the y-axis of the profile sheet, and place a small dot above each mark on the paper strip which is at that particular elevation (See Figure 7).
7. Repeat step 6 until you have made a small dot on the profile sheet at the appropriate elevation for each mark on the paper strip including the labeled points that fall between lines of elevation and need to be guesstimated (See Figure 7).
8. Now draw a smooth line connecting the dots on the profile sheet to create a topographic profile. If you recorded an up or down arrow on your paper strip make sure your smoothed line rises above (up arrow) or dips below (down arrow) that elevation line between the two dots (see Fig. 8).
9. Calculate the *vertical exaggeration* in your topographic profile. This is a measure of the variation between the vertical (or elevation) scale of your *topographic profile sheet* and the horizontal (or distance) scale, which is the same as the map scale. As it implies the vertical dimension of your profile is often exaggerated thus sacrificing reality for clarity. To calculate vertical exaggeration, use the following formula:

$$\text{vertical exaggeration} = (\text{map scale (in feet)} / \text{vertical scale (in feet)})$$

For example, if the map scale is 1 inch=2000 feet and the vertical scale is 1 inch=1000 feet, then 2000 divided by 1000 equals a vertical exaggeration of 2. This means that a change in elevation on the profile sheet appears two times steeper than it actually is. Ideally the vertical exaggeration should be as close to 1 as possible.

Exercise 3—Slope Percent

Provide each student with a copy of the *simplified topographic map* (See page 8). Instruct them to locate the line labeled CD on the map and calculate its *slope percent*. Slope percent is a measure of a slope's steepness. It is also referred to as grade. To calculate slope percent, use the following formula:

$$\text{slope \%} = (\text{rise} / \text{run}) \times 100$$

where *rise* is the change in elevation and *run* is the horizontal distance between two points.

Steps:

1. Count the number of contour lines between C and D, but don't count the one at point C (*Answer: 5*).
2. Locate the contour interval in the map legend (*Answer: 100 feet*).
3. Multiply the number of contour lines in step 1 by the contour interval in step 2 to calculate the *rise* (*Answer: 5 x 100 feet = 500 feet*).
4. Measure the length of line CD (*Answer: 1 1/16 or 1.0625 inches*).
5. Locate the verbal scale in the map legend (*Answer: 1 inch=2000 feet*).
6. Multiply the number of inches in step 4 by the number of feet in step 5 to calculate the *run* (*Answer: 1.0625 inches x 2000 feet = 2125 feet*).
7. Divide the *rise* in step 3 by the *run* in step 6 and multiply the result by 100 to calculate the *slope percent* (*Answer: 500 feet/2125 feet x 100 = 23.5%*).

Exercise 4—Determining Elevation

Provide each student with a copy of the *topographic map* (See page 13). Instruct them to determine the elevation of points A-E.

Steps:

1. Locate the contour interval in the map legend (*Answer: 20 feet*).
2. Calculate the interval between index contours (*Answer: 5 intervals between index contours x 20 feet per interval = 100 feet*).
3. Locate a labeled index contour near the point and determine if the point is above or below the index.
4. Use number of intervening index contours and contour lines to calculate the elevation. For example, if the labeled index contour is 6700 feet, and there are 2 index contours and 3 additional contour lines between it and the point the elevation would be $6700+(2 \times 100)+(3 \times 20)=6700+200+60=6960$ feet. To check your answer begin the process from a different index contour.

Point A: Nearest labeled index contour is 6900 feet. Point A appears to be below the index contour, however there are no other contour lines separating the labeled index contour from the unlabeled index contour between it and Point A, therefore the elevation of the index contours is the same. There are 2 contour lines above the unlabeled index contour (+40 feet), therefore the elevation is greater than 6940, but less than 6960 (*Answer: 6941-6959 feet*).

Point B: Nearest labeled index contour is 6900 feet. Point B is above the index contour (add). There are 3 intervening index contours plus 2 more contour lines (+340 feet), therefore the elevation is greater than 7240, but less than 7260 (*Answer: 7241-7259 feet*).

Point C: Nearest labeled index contour is 7000 feet. Point C is below the index contour (subtract). There are no intervening index contours, and 2 contour lines, however the second is a concentric circle, and thus is at the same elevation as the first (-20 feet), therefore the elevation is greater than 6980, but less than 7000 (*Answer: 6981-6999 feet*).

Point D: Nearest labeled index contour is 6800 feet. Point D is above the index contour (add). There are 6 intervening index contours and 7 more contour lines (+740 feet—Oops! The map maker made a mistake, the fifth one should have been an index contour), therefore the elevation is greater than 7540, but less than 7560 (*Answer: 7541-7559 feet*).

Point E: Nearest labeled index contour is 6800 feet. Point E is above the index contour (add). There is 1 intervening index contour and 1 more contour line (+120 feet), therefore the elevation is greater than 6920 but less than 6940 (*Answer: 6921-6939 feet*).

Extensions

1. Internet Assignment—Have students visit the *National Geophysical Data Center* web site at www.ngdc.noaa.gov. From the home page click on *Geomagnetic Data & Models*. Select *Calculators* from Quick-Links, then choose *declination calculator* on the next page. Have them use the declination calculator to determine the magnetic declination for their hometown (zip code needed) on their birth date and for their birthday in the current year. Each entry will provide them with the magnetic declination (degrees and minutes east or west) and its rate of change. Have them answer the following questions:
 - a. What is the total difference between the two magnetic declinations in degrees and minutes (Note: There are 60 minutes in one degree)?
 - b. Has the rate of change increased or decreased?
 - c. What is the average rate of change (Total change/Student's age)?
2. Group Project—Construct a three dimensional elevation model of Fossil Butte National Monument using the instructions and templates provided on www.nps.gov/fobu/forteachers/curriculummaterials.htm and select the link *Modeling Fossil Butte*.

Assessment Plan

Assessment 1—Evaluating Changes in Elevation

In this assessment students will use the *simplified topographic map* to visually determine whether the eastern or western flank of Fossil Butte is steeper and provide their reasons. Then using the line labeled AB on the map they will calculate the slope percent for each flank. They will use this information to make an evaluation of their original hypothesis. Next they will make a sketch of the eastern and western flanks before preparing a topographic profile of each and comparing their drawings with the profiles. Finally they will prepare a topographic profile for the entire length of line AB.

A student worksheet for Assessment 1 is provided on pages 14 and 15 with an answer key on pages 16 and 17.

Assessment 2—Planning a Trail

In this assessment a team of 3 students will use their knowledge of topographic maps and slope percent to plan a hiking trail. They will be provided specific guidance to help them evaluate their route and several additional tasks.

A student worksheet with special planning map for Assessment 2 is provided on pages 18 and 19. An answer key for the additional tasks is provided on page 20.

8 Simple Rules for Interpreting Topographic Maps

1. Contour lines are brown in color and used to show elevation (height above or below sea level). Each contour line represents just one elevation.
2. Contour lines never cross each other.
3. The area inside a closed contour line is higher in elevation (uphill) and the area outside is lower in elevation (downhill).
4. Every fifth contour line, known as an *index contour*, is darker and wider, and labeled with its elevation.
5. The more closely spaced the contour lines are, the steeper the terrain is.
6. The *rule of Vs* states that where contour lines cross streams they are bent to form a V shape, and the sharp end of the V points uphill (Figure 1).
7. The *rule of Os* states that adjacent contour lines forming a series of roughly concentric circles represent hilltops or mountain peaks. Often an X is placed in the interior of the smallest circle to represent the highest point and its elevation is given (Figure 2).
8. *Depressions* look similar to hilltops except short tic marks called hachures are placed perpendicular to the inside edge of the contour line and point downhill (Figure 3).

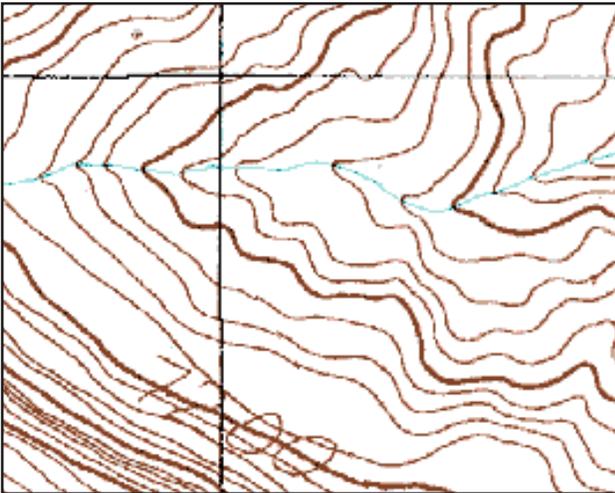


Figure 1

Figure 1 (*Rule of Vs*)—Shows a stream (in blue) around which the contour lines are bent to form crude Vs. The tip of the V points upstream (uphill). Thus the stream in this figure is flowing from left to right or downhill. Notice the closely spaced contours in the lower left indicating its very steep. Also take note of the index contour labeled 7200. There are four more that are not labeled with their elevation in the figure. What are their elevations given a contour interval of 20 feet?

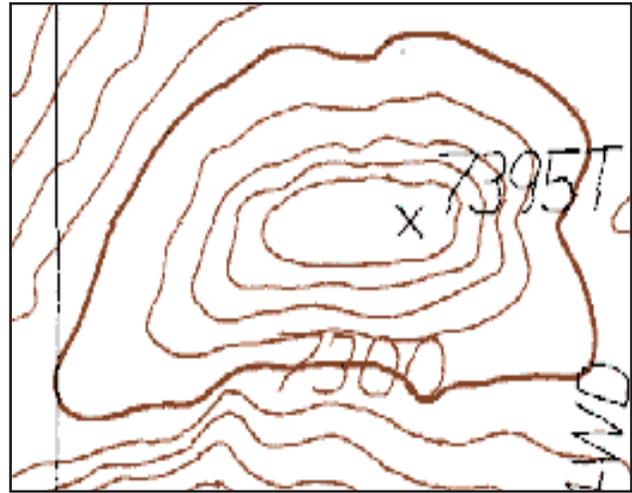


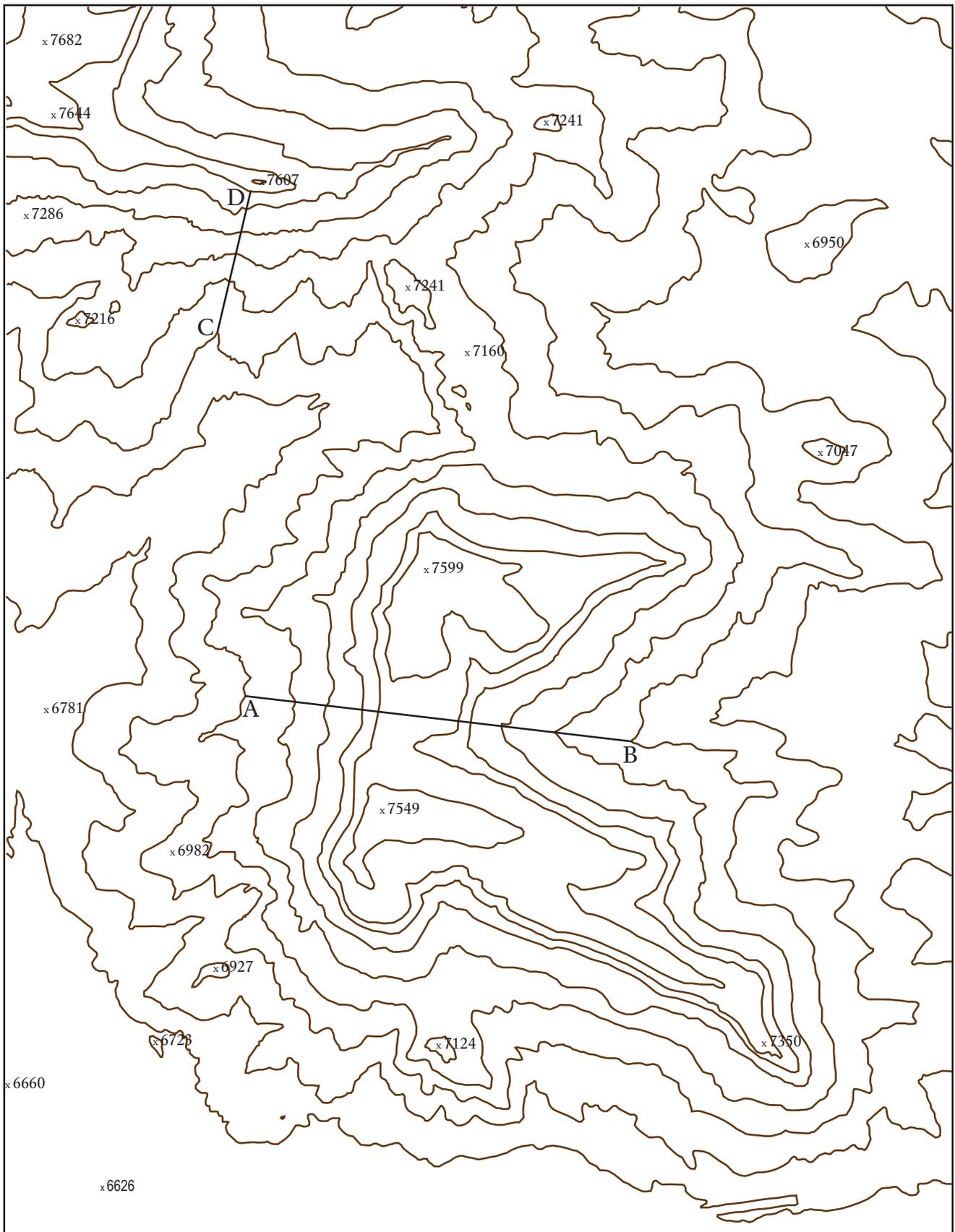
Figure 2

Figure 2 (*Rule of Os*)—Shows a hilltop with the highest point marked with an X and its elevation, 7359. Note that the interior of the each closed contour is uphill and the exterior is downhill. Notice the index contour labeled 7300. What is the contour interval?

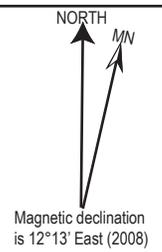


Figure 3

Figure 3 (*Depressions*)—Shows several depressions called sinkholes. The hachures perpendicular to the contour lines are pointing downhill. The water in these depressions is another clue telling us they are not hilltops. Notice the index contour labeled 175 near the right edge of the figure. What is the contour interval on this map?

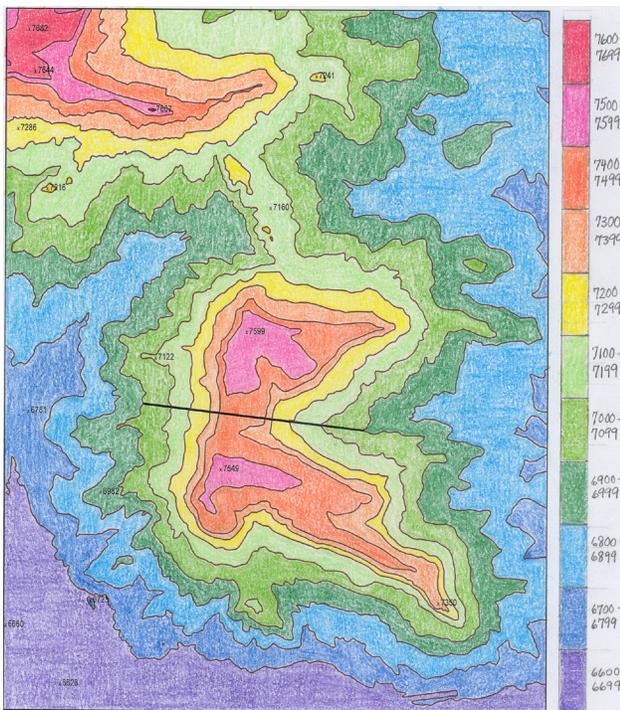


1 inch = 2000 feet
 1:24,000
 Contour interval = 100 ft

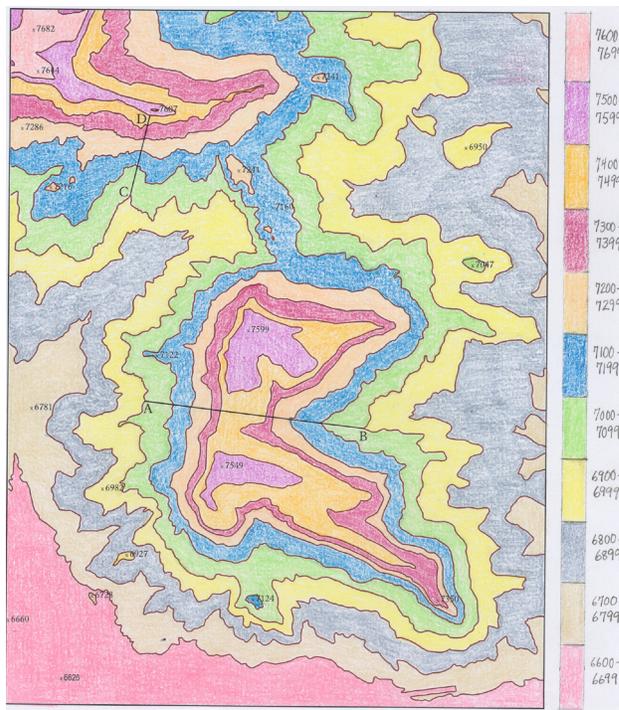


Simplified Topographic Map with index contours only showing a portion of Fossil Butte National Monument including Fossil Butte, the Wasatch Saddle, and a portion of Cundick Ridge.
 Compiled from USGS Topographic Maps (1:24,000) of Fossil, Wyoming and Nugget, Wyoming quadrangles.

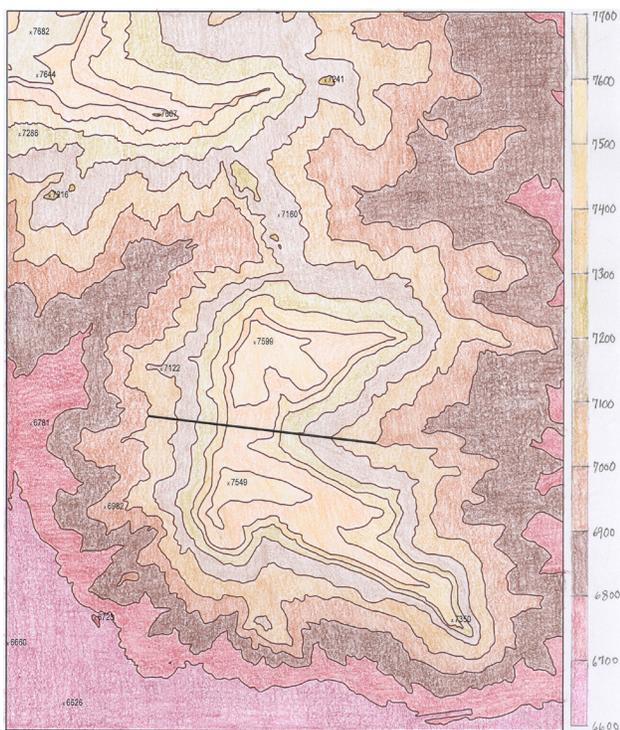
4 Examples of the Conversion to a Shaded Relief Map



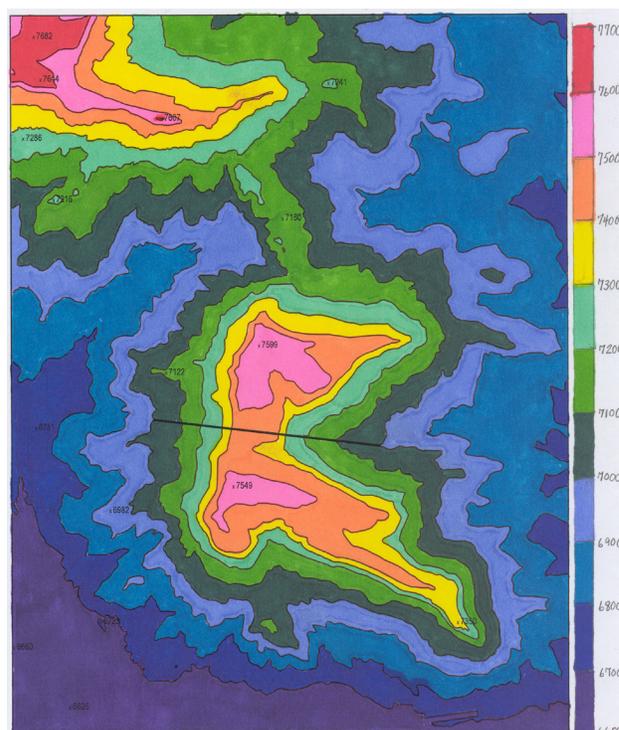
Example 1—A cool-to-warm color pattern using colored pencils. The pattern seeks to imitate the visible light spectrum (ROY G BIV). This produces a reasonably good 3-D effect with cooler colors for lower elevations and warmer for higher.



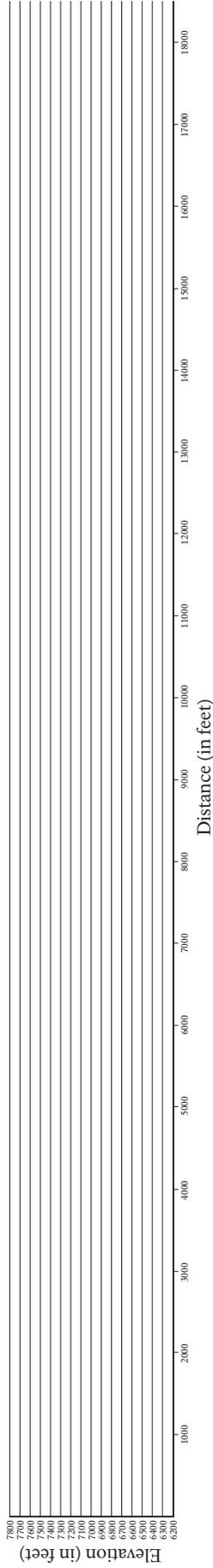
Example 2—A random color pattern using colored pencils. This produces a very poor 3-D effect and such patterns should be discouraged.



Example 3—A dark-to-light color pattern using colored pencils. The pattern employs shades of brown. This produces a reasonably good 3-D effect that is more muted than Example 1.



Example 4—A cool-to-warm color pattern similar to Example 1, but using colored markers. This produces a reasonably good 3-D effect that is less muted than Example 1.



Topographic Profile Sheet (for use with 1:24,000 scale maps)

1. What is the horizontal (distance) scale? 1 inch = _____ feet
2. What is the vertical (elevation) scale? 1 inch = _____ feet
3. What is the vertical exaggeration? $VE = \text{vertical scale (in feet)} / \text{horizontal scale (in feet)} = \underline{\hspace{2cm}}$

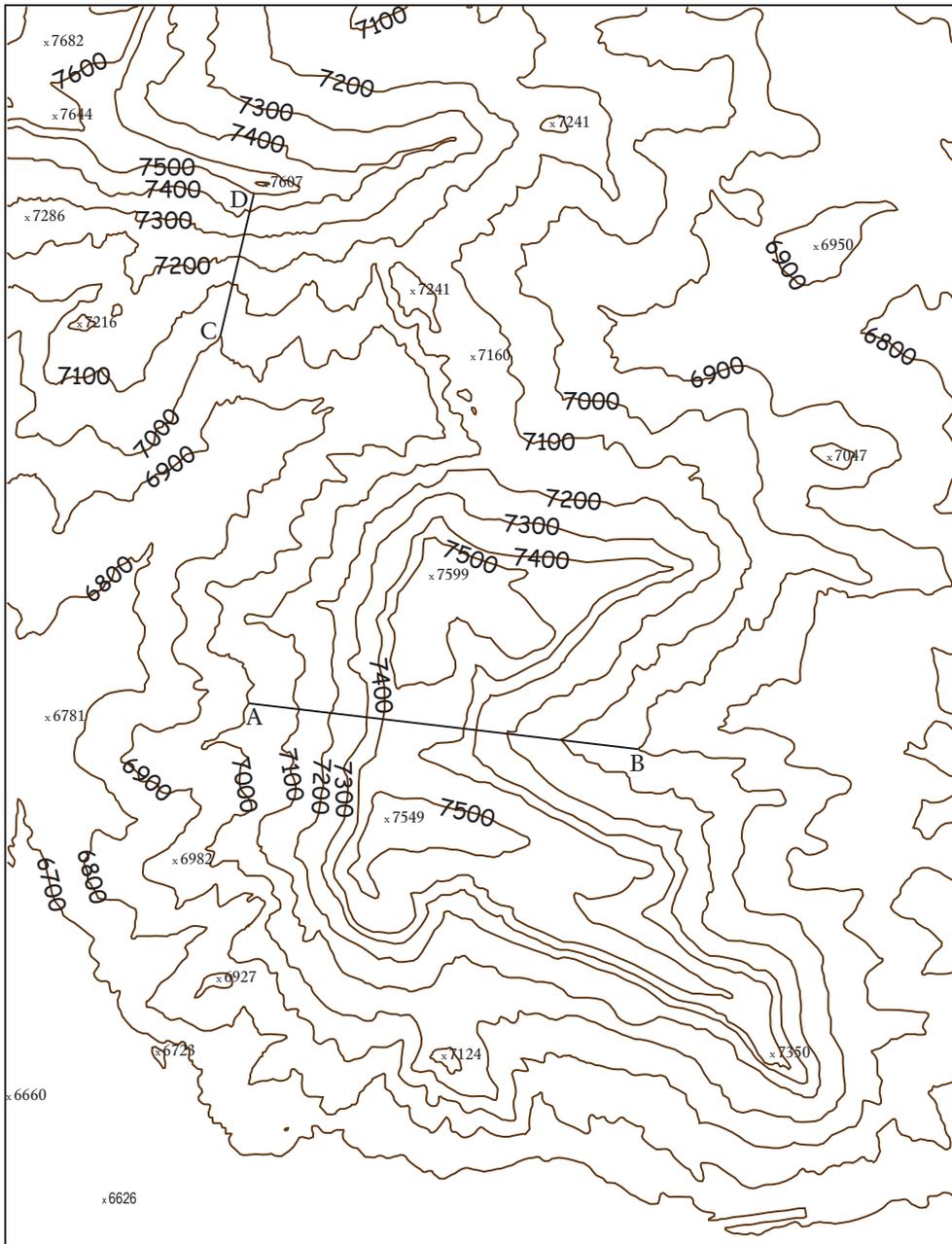


Figure 4

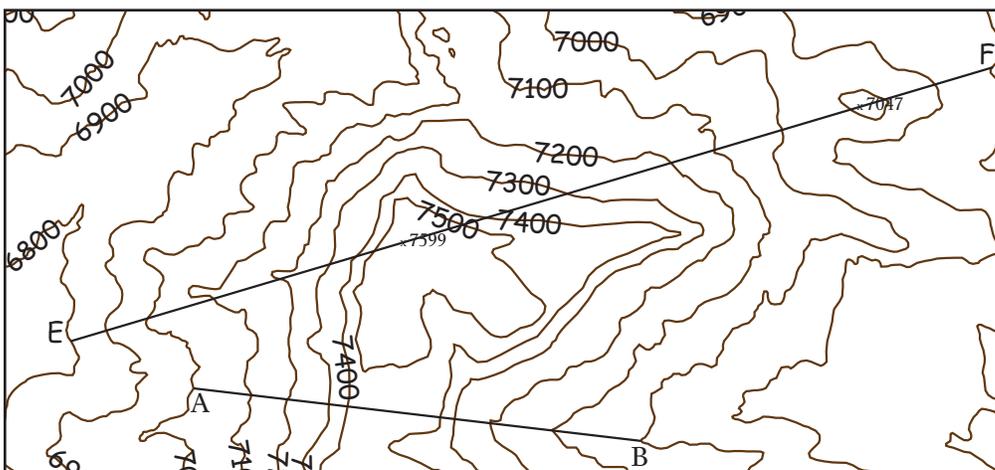


Figure 5

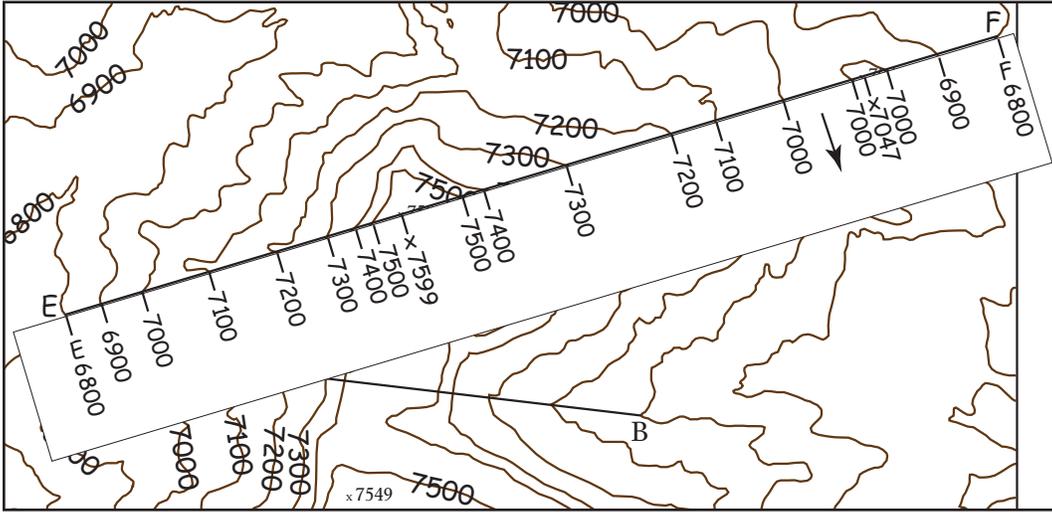


Figure 6

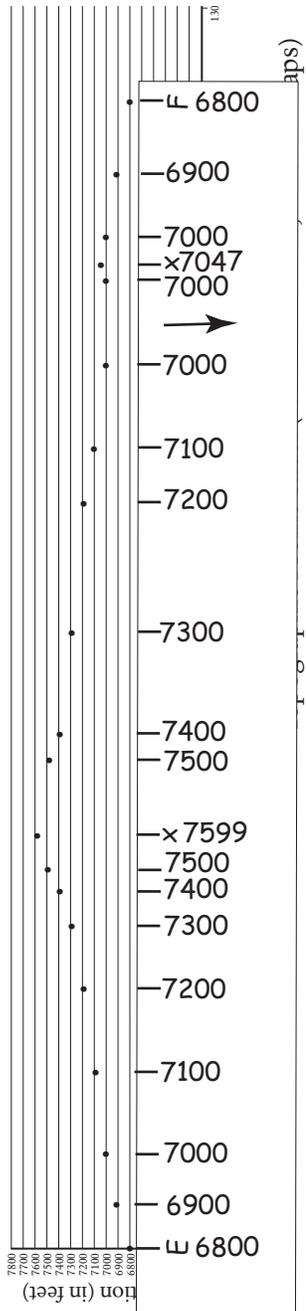
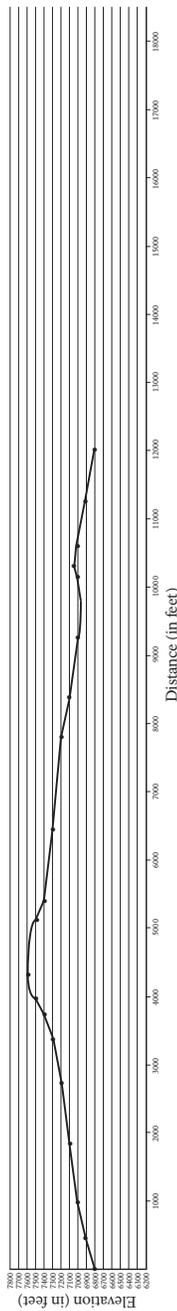


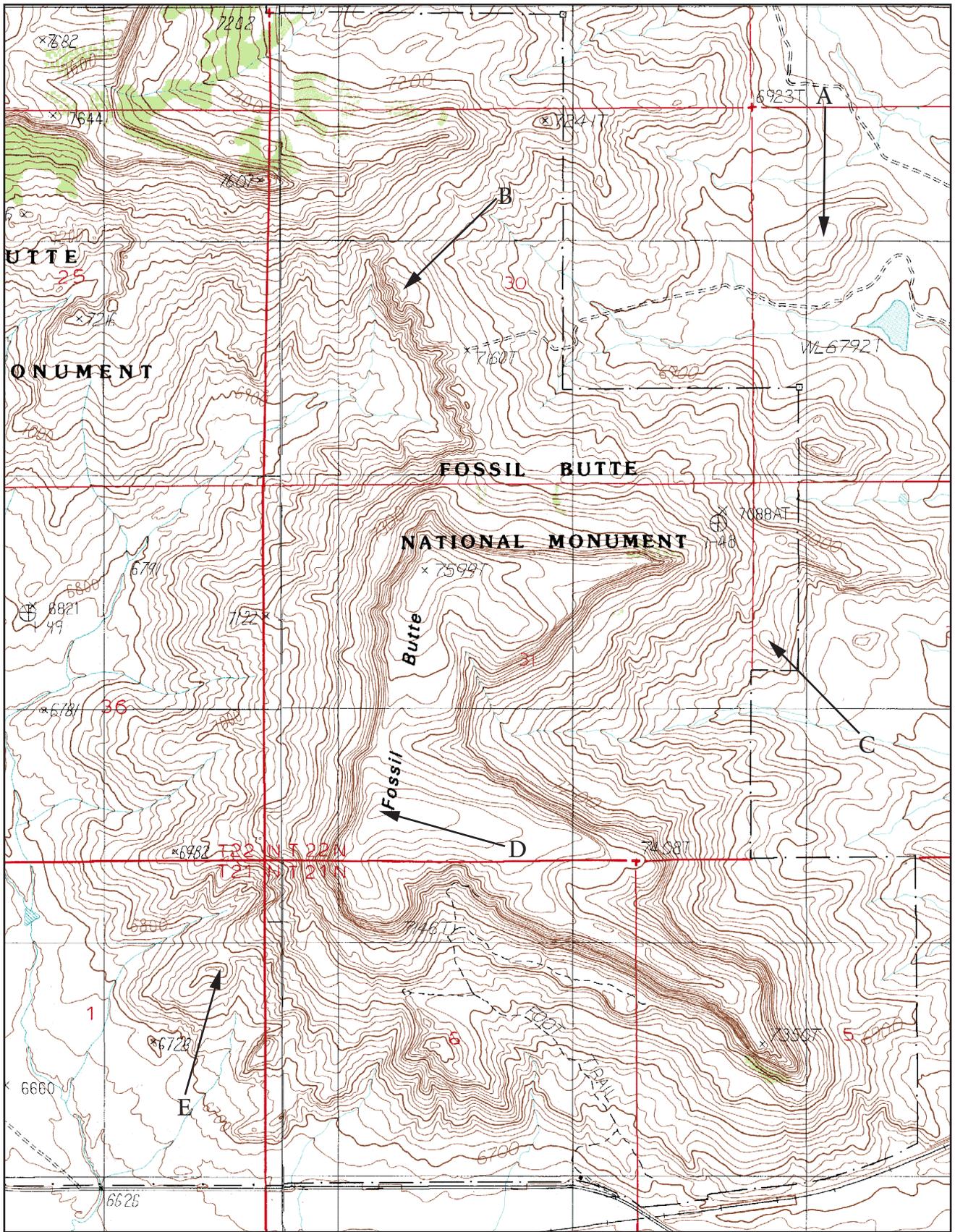
Figure 7



Topographic Profile Sheet (for use with 1:24,000 scale maps)

1. What is the horizontal (distance) scale? 1 inch = 2000 feet
2. What is the vertical (elevation) scale? 1 inch = 1600 feet
3. What is the vertical exaggeration? VE=vertical scale (in feet)/horizontal scale (in feet)= $\frac{2000}{1600} = 1.25$

Figure 8



Feet 1000 2000 4000 6000 Feet

1 inch = 2000 feet
1:24,000
Contour interval = 20 ft



Topographic Map showing a portion of Fossil Butte National Monument including Fossil Butte, the Wasatch Saddle, and parts of Cundick Ridge.

Compiled from USGS Topographic Maps (1:24,000) of Fossil, Wyoming and Nugget, Wyoming quadrangles.

Evaluating Changes in Elevation

1. Locate Fossil Butte on your map. It is the central feature marked at its top by two elevations (7549 and 7599). With a little imagination, it looks a bit like the state of Louisiana. Look at the eastern (right) and western (left) slopes of Fossil Butte. Which appears steeper to you? What makes you think so?
2. Locate the Line AB cutting through the center of Fossil Butte on your map. Use this line to mathematically evaluate the steepness of the eastern and western slopes of Fossil Butte. The measure of a slope's steepness is called *slope percent*. It is also known as its grade. To calculate slope percent use the following formula:

$$\text{Slope \%} = (\text{rise/run}) \times 100$$

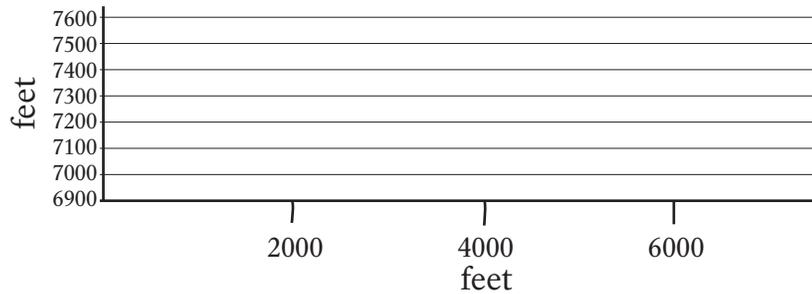
where *rise* is the change in elevation (vertical distance) between two points, and *run* is the horizontal distance between the two points. For example, if point A is at 6900 feet and point B is at 7000 feet, then the rise is 7000-6900, or 100 feet. If the horizontal distance (run) between point A and point B is 500 feet, then the slope percent is $(100/500) \times 100$, or 20%.

Evaluate the slope percent of the eastern and western flanks of Fossil Butte for the following elevation intervals: 7000-7200, 7200-7400 and 7000-7400. Use a ruler and the verbal scale (1 inch = 2000 feet) to determine the run.

Elevation Interval (in feet)	Rise	Eastern Slope			Western Slope		
		Run (inches)	Run (Feet)	Slope %	Run (inches)	Run (Feet)	Slope %
7000-7200							
7200-7400							
7000-7400							

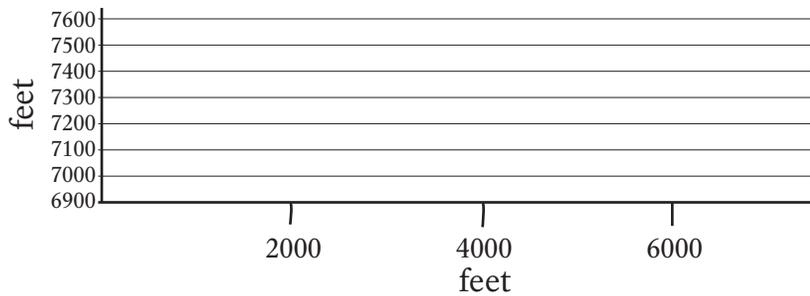
3. Visualize the grade of the eastern and western slopes of Fossil Butte and make a sketch of each below.

4. Construct a topographic profile of the eastern and western slope between 7000 and 7400 feet in elevation along the Line AB. Be sure to start both slope profiles at 7000 feet from the y-axis so you can easily compare their steepness. Do the profiles look like your previous sketches?



Vertical Scale 1 inch = 750 feet Horizontal Scale 1 inch = 2000 feet
 Vertical Exaggeration= 2.67x (for use with 1:24,000 scale map)

5. Construct a topographic profile of Fossil Butte for the entire length of the Line AB on your map. Assume that the highest point between the two 7400 contours is 7460 feet.



Vertical Scale 1 inch = 750 feet Horizontal Scale 1 inch = 2000 feet
 Vertical Exaggeration= 2.67x (for use with 1:24,000 scale map)

Evaluating Changes in Elevation

1. Locate Fossil Butte on your map. It is the central feature marked at its top by two elevations (7549 and 7599). With a little imagination, it looks a bit like the state of Louisiana. Look at the eastern (right) and western (left) slopes of Fossil Butte. Which appears steeper to you? What makes you think so?

The left (western) slope appears steeper. The contour lines appear to be closer together.

2. Locate the Line AB cutting through the center of Fossil Butte on your map. Use this line to mathematically evaluate the steepness of the eastern and western slopes of Fossil Butte. The measure of a slope's steepness is called *slope percent*. It is also known as its grade. To calculate slope percent use the following formula:

$$\text{Slope \%} = (\text{rise/run}) \times 100$$

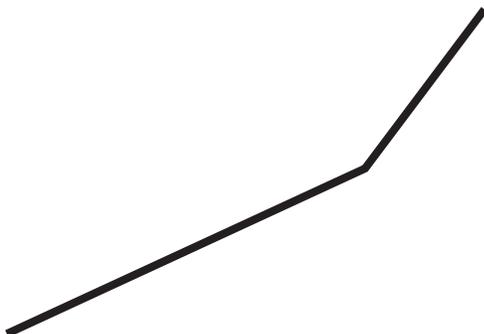
where *rise* is the change in elevation (vertical distance) between two points, and *run* is the horizontal distance between the two points. For example, if point A is at 6900 feet and point B is at 7000 feet, then the rise is 7000-6900, or 100 feet. If the horizontal distance (run) between point A and point B is 500 feet, then the slope percent is $(100/500) \times 100$, or 20%.

Evaluate the slope percent of the eastern and western flanks of Fossil Butte for the following elevation intervals: 7000-7200, 7200-7400 and 7000-7400. Use a ruler and the verbal scale (1 inch = 2000 feet) to determine the run.

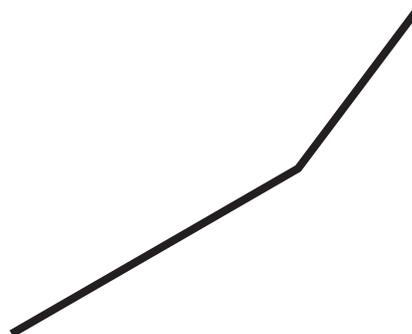
Elevation Interval (in feet)	Rise	Eastern Slope			Western Slope		
		Run (inches)	Run (Feet)	Slope %	Run (inches)	Run (Feet)	Slope %
7000-7200	200	15/16	1875	10.7	9/16	1125	17.8
7200-7400	200	5/16	625	32.0	3/8	750	26.7
7000-7400	400	1 1/4	2500	16.0	15/16	1875	21.3

3. Visualize the grade of the eastern and western slopes of Fossil Butte and make a crude sketch of each below.

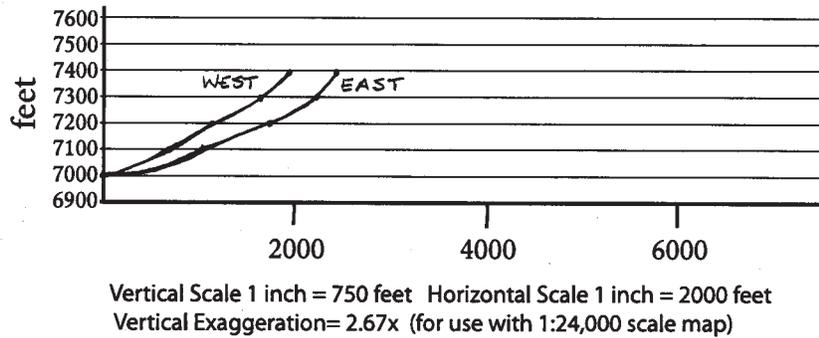
East



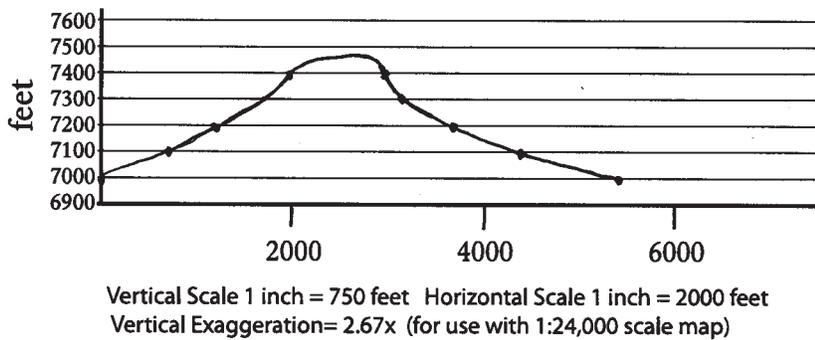
West



4. Construct a topographic profile of the eastern and western slope between 7000 and 7400 feet in elevation along the Line AB. Be sure to start both slope profiles at 7000 feet from the y-axis so you can easily compare their steepness. Do the profiles look like your previous sketches?



5. Construct a topographic profile of Fossil Butte for the entire length of the Line AB on your map. Assume that the highest point between the two 7400 contours is 7460 feet.



Planning a Trail

The superintendent of Fossil Butte National Monument and his chief of resource management have hired you and two fellow students as consultants based on your superior knowledge of topographic maps. They would like you to plan a hiking trail from the parking lot (P) that will allow an average visitor in good health to visit two historic sites on the southern face of Fossil Butte in two hours or less time. Assume a leisurely walking speed of 1.5 miles per hour. The following guidance has been provided to your team:

1. It is suggested that you plan a loop trail to visit the Haddenham cabin (1) and run a spur from that trail to reach the old fossil quarry (2). To minimize ground disturbance and allow hikers to choose which site they visit first, you should consider a trunk trail from the parking lot to the beginning of the loop as well.
2. The Organic Act of 1916, which created the National Park Service, states that it is our mission “...to conserve scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.”
3. The act of congress that created Fossil Butte National Monument on October 23, 1972 has also charged us with “...preserv[ing] for the benefit and enjoyment of present and future generations outstanding paleontological sites and related geologic phenomena, and to provide for the display and interpretation of scientific specimens.”
4. Therefore, the superintendent and chief of resource management are most concerned with visitor safety and resource protection. Your plan should avoid streams to minimize the danger from flash flooding. Stay away from steep slopes and maintain trail grades of less than 10% to maximize visitor comfort and minimize erosion. Occasionally grades of 15% are permissible but distances should not exceed 100 yards. The integrity of the Green River Formation (primary fossil-bearing rocks) above the 7300 foot contour line should be preserved though some minor disturbance will be necessary in building the spur trail to reach the old fossil quarry.

To evaluate the grade of the trail you will need to use a measure of steepness called *slope percent*. It can be calculated using the following formula:

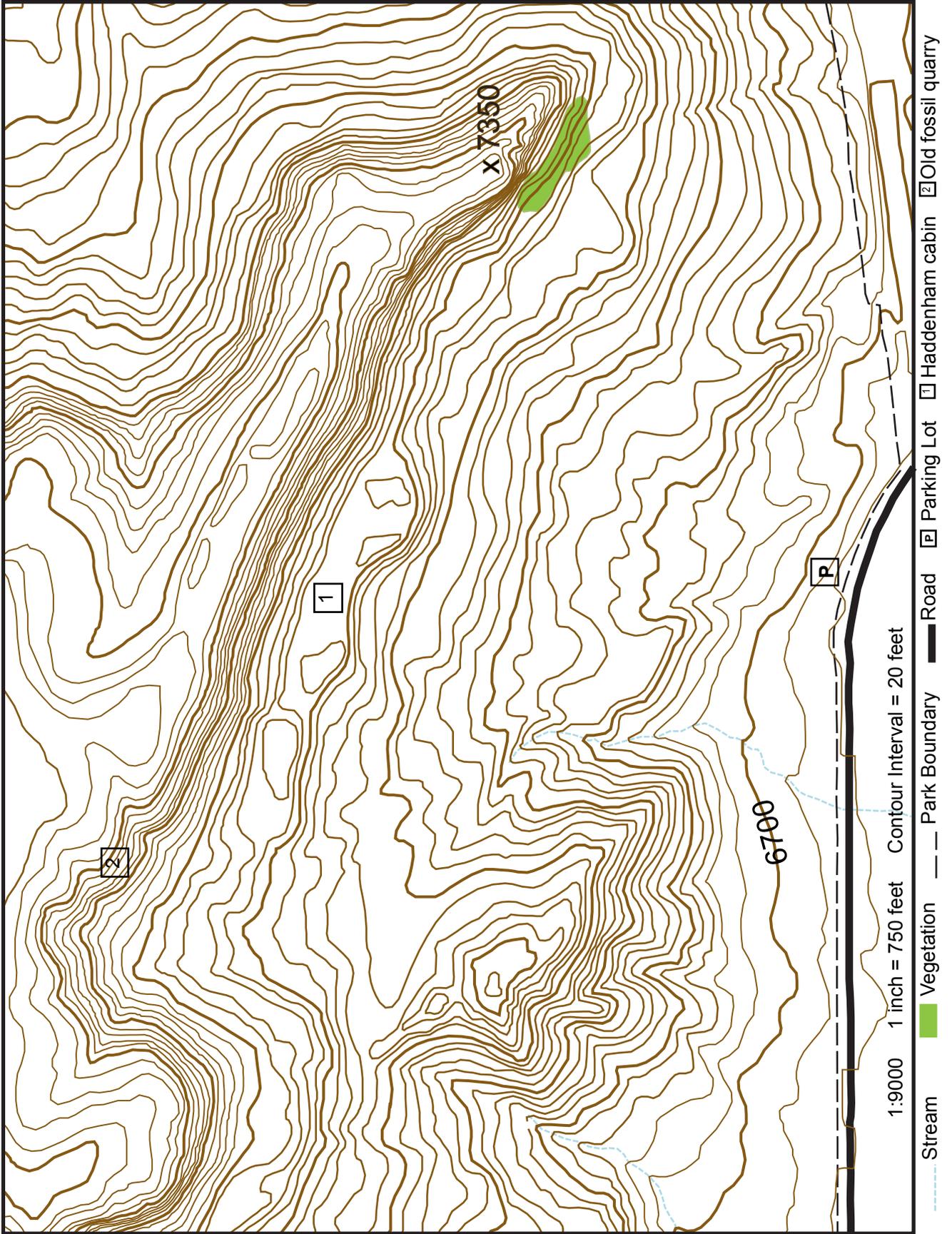
$$\text{slope \% (or grade)} = (\text{rise} \div \text{run}) \times 100$$

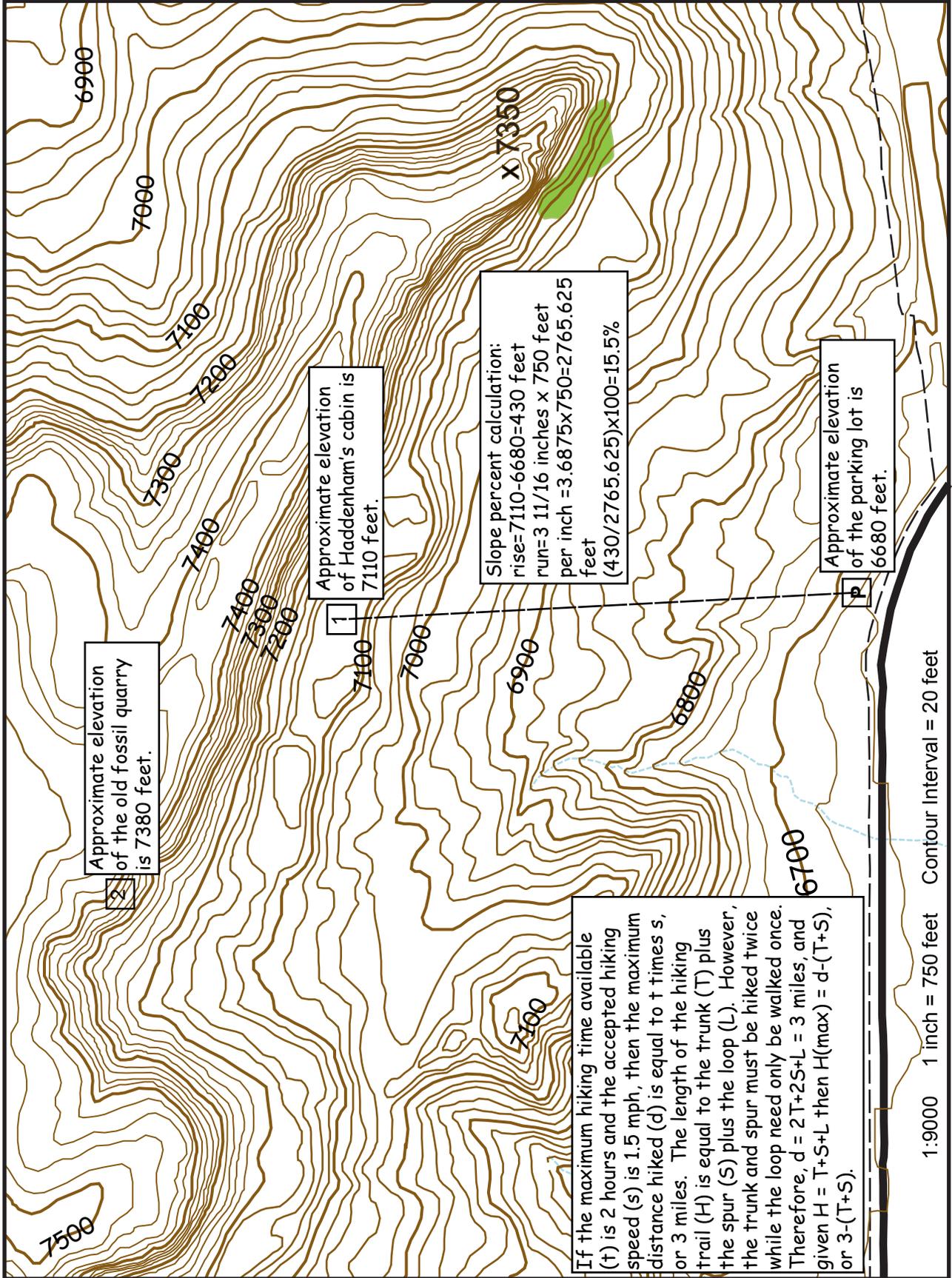
where *rise* is the change in elevation (vertical distance) between two points and *run* is the horizontal distance between those same points.

Use the map on the following page to plan the trail.

Perform these additional tasks:

1. Label the unlabeled index contours.
2. Determine the approximate elevation of the parking lot, Haddenham cabin and old fossil quarry. Use the center point of the box as the approximate position. If that point is on a contour line that is its approximate elevation, otherwise choose an approximate elevation halfway between the contour lines to either side.
3. Calculate the average slope percent along a line connecting the parking lot and Haddenham cabin.
4. Based on a leisurely walking speed, what is the maximum length of the trail you can plan? (Don't forget that the trunk and spur will be traveled up and back.)





If the maximum hiking time available (t) is 2 hours and the accepted hiking speed (s) is 1.5 mph, then the maximum distance hiked (d) is equal to t times s, or 3 miles. The length of the hiking trail (H) is equal to the trunk (T) plus the spur (S) plus the loop (L). However, the trunk and spur must be hiked twice while the loop need only be walked once. Therefore, $d = 2T + 2S + L = 3$ miles, and given $H = T + S + L$ then $H(\max) = d - (T + S)$, or $3 - (T + S)$.