Lab 4: Topographic and Geologic Maps

Synopsis

Exploring a planetary surface requires the use of maps that portray the shape and slopes of the land surface and the types of materials that compose the landscape. In this lab, you will learn how to locate yourself on a topographic map and use these skills to locate on a topographic map your previously identified mineral and rock samples from Painted Canyon. You will construct a topographic profile to learn how to evaluate the steepness of slopes. Finally, you will produce a simplified geologic map for an interesting location on Earth.

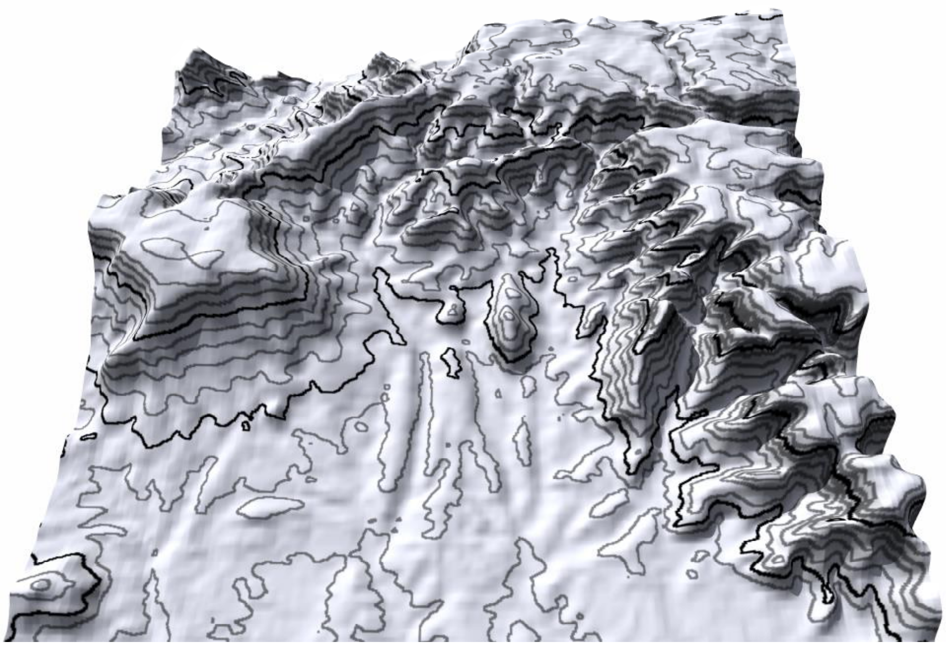


Figure 4-1. Three-dimensional perspective of contours superimposed on topography for an area near Sedona, Arizona. Note the close spacing of contours along steep slopes, and the wide spacing of contours where slopes are less steep. Also observe the pattern of contours for different types of features, such as small hills, ridges, mesas (flat-topped mountains), and narrow versus wide valleys.

Introduction

In the first weeks studying rocks and minerals in Painted Canyon, you were provided with 3D perspectives showing the locations of the samples, but you did not have to do anything with that information. Now, you need to document where each rock sample was collected by locating it on a topographic map. The topographic map of Painted Canyon (in the worksheet and near the end of these instructions) shows the elevation of the land surface and will be used to locate your samples.

Goals for This Week

- Understand what a topographic map shows (e.g., contours) and be able to recognize features (hills, ridges, valleys, etc.) on a topographic map.
- Be able to construct a topographic profile from a topographic map.
- Begin to understand what a geologic map shows, by constructing a simple geologic map.

Exercise 4A: Visualizing Topography

You will use the computers to interact with movies of different types of landscape features, such as hills and valleys.

- ☐ You should go to the computer and go to the SES121 home page at:

http://reynolds.asu.edu/SES123/

- ☐ Find the section entitled Topographic and Geologic Maps (Lab 4) and click on the link for the *Visualizing Topography* website. This leads you to a computer-based module that will help you understand topographic maps. For this part, put your observations and answers in the appropriate spaces on ***Worksheet 4A-1***.
- ☐ Examine *Figure 4-3*, which shows how various types of topographic features appear on a topographic map.
- ☐ Read *Box 4-1*, which provides useful information about topographic maps. We recommend you not skip this step (or the one above) unless you are very familiar with reading a topographic map.

Exercise 4B: Playing in the Sandbox

- ☐ Any time during the lab when the topographic sandbox is available, go over and reshape the sand into the topographic features described below. As you do this, the sensor-computer-projector system will draw topographic contours for whatever shape you create in the sand. You do not need to fill out any worksheet for this part of the lab, but it is very informative and fun so don't miss out.
- ☐ Using the sandbox, shape the sand to produce a topographic feature that matches the general features of the contour map to the right. The actual number of contours do not matter, just the overall shape.

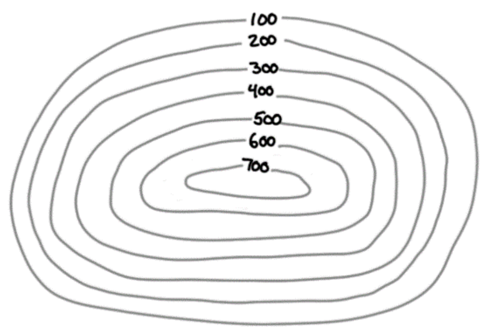
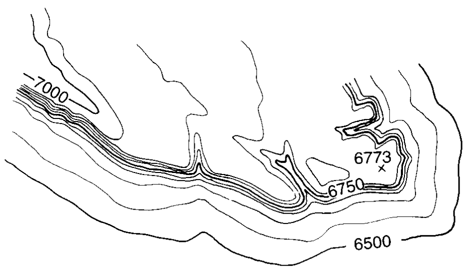


Figure 4-2. Contour map of a simple, fairly round hill

- ☐ Using the sandbox, shape the sand to produce a topographic feature that matches each of the following types of features.
    - Mesa, which is a hill with a flat top and steep sides
    - Hill with a valley cutting into one side
    - Round hill with a ridge on one side
    - Crater with a central depression (the sandbox computer does not put tick marks on contours surrounding the depression)

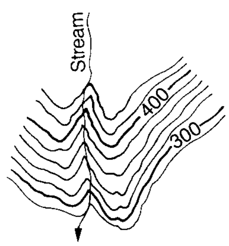
Principles: Every point on a contour line has the same elevation. Elevations on one side of the line are higher than elevations on the other side of the line.

Example: A circular hill, whose highest point is 1628 feet above sea level, is flanked by a smaller, lower hill to the east.



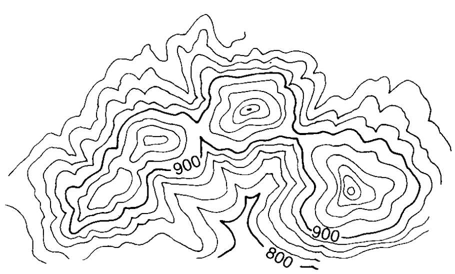
Principles: Contour lines do not cross each other or split. Widely spaced contour lines represent gentle slopes; closely spaced contour lines indicate steep slopes.

Example: A flat-topped mountain (mesa) in the center is surrounded by a cliff (closely spaced contours) on the west, south, and east sides.



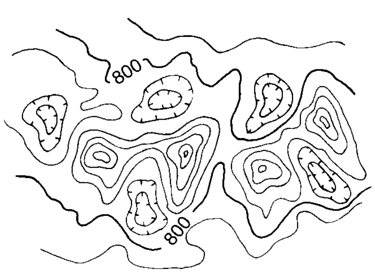
Principle: Contour lines that cross stream valleys form a "V" pointing upstream.

Example: A small stream drains southward through a small valley (gully), in the direction of the arrow.



Principle: Concentric, closed contour lines represent a hill.

Example: Four hills form a curved ridge and are separated by small topographic low points (saddles), where the contours “pinch” together.



Principle: Closed depressions (representing basins with no outlet) are shown by closed contours with hachures (short lines) that point inward toward the depression.

Example: Small depressions, shown with hachures, sit on both sides of a line of four hills. The depressions are like the closed crater in the volcano-in-a-box. The hills are each shown by closed contours without hachures.

Figure 4-3. Examples of topographic features on contour maps.

Exercise 4C: Locating Yourself in Painted Canyon

Examine the topographic map of Painted Canyon on the *worksheet*. *Box 4-2* contains some tips about how you would locate yourself on a topographic map by looking at the contours and other features shown on the map.

- ☐ Read *Box 4-2*, which provides useful tips about locating points on a topographic map. We recommend you not skip this step unless you are very familiar with reading a topographic map.
- ☐ From links on the SES121 website, examine the 3D perspectives showing the locations of the samples of igneous, sedimentary, and metamorphic rocks you examined earlier in the semester. Use the 3D perspectives to locate each of these samples on the topographic map of Painted Canyon in the ***Worksheet Map 4C-1***.

Exercise 4D: Creating a Topographic Profile

To further explore the relationship between contour lines and topography of the landscape, your team will construct a type of figure, called a *topographic profile,* which allows you to see the "side view" of a feature on a topographic map. It's like taking a slice out of a hill and looking at it from the side (*Figure 4-4*).

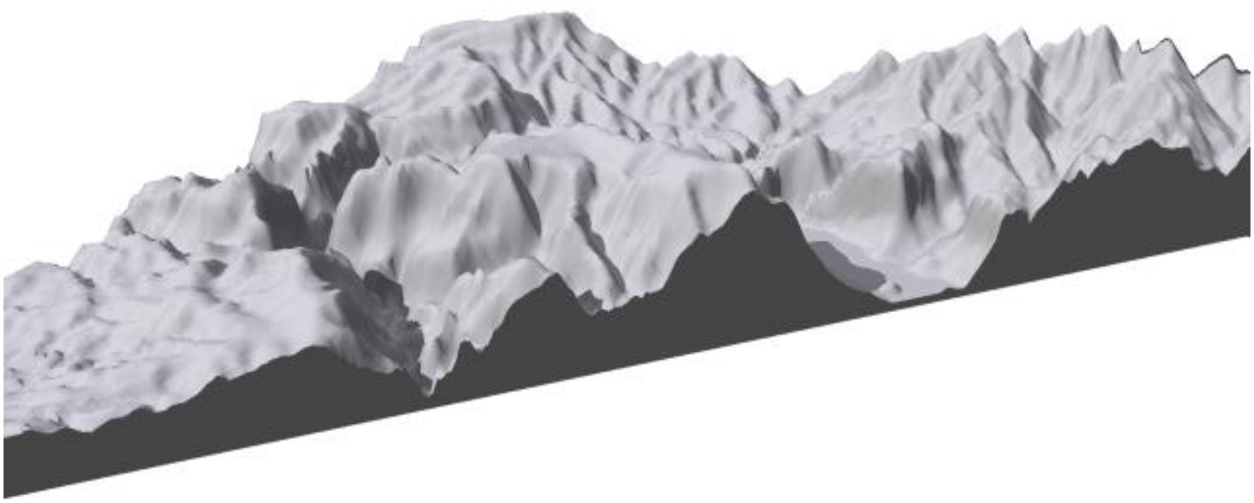
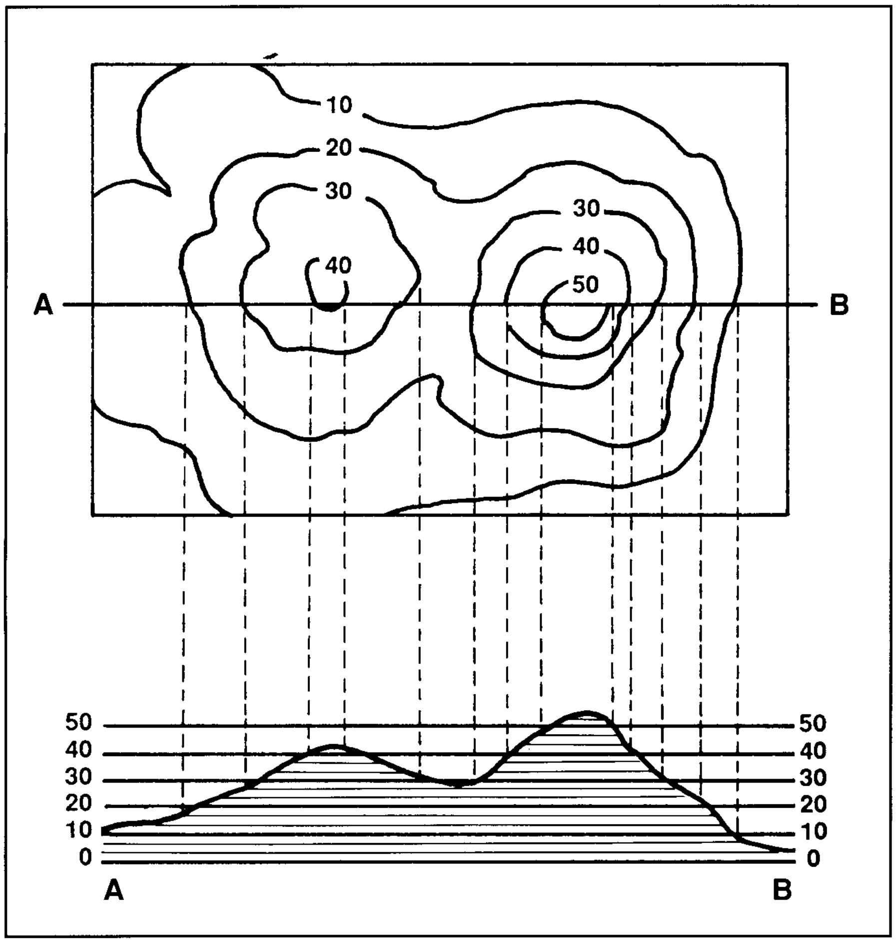


Figure 4-4. Three-dimensional perspective showing a topographic profile along the front.

You should complete the following steps:

- ☐ Near the end of this document and on your worksheet, is a map of Painted Canyon with a line A-B drawn in a northeast-southwest direction. Use the topographic profile grid sheet (***Worksheet 4D-1***) at the end of the worksheet. Place the top edge of the profile grid sheet along the profile line A-B on this map and make a small tick mark on the edge at every point where the profile line intersects a major contour line (100, 200, etc.). Label each tick mark with the number of the corresponding contour line.
- ☐ Your profile grid sheet should now have small tick marks along the top edge, labeled with numbers 100, 200, 300, etc. The same number may appear more than once, such as on opposite sides of the canyon or opposite sides of a hill.
- ☐ On your profile grid sheet, draw a thin dashed line vertically downward from the tick numbered "100" placing a dot where it intersects the horizontal line labeled "100". Do the same for the ticks numbered "200", intersecting the line labeled "200", and so on, continuing this process for the rest of the tick marks.
- ☐ When you are done, most lines of the profile grid will have dots that correspond to where a contour line crossed your profile line. The points should be lowest in the valley, which is in the center of the grid.
- ☐ Now connect the dots using curved lines to accurately represent the true shape of the landscape.
- ☐ The SES123 website has links to movies illustrating what a topographic profile represents.



The procedure you just followed to draw a profile from your simple topographic map can be used to draw a topographic profile from a more detailed topographic map, like those published by the U.S. Geologic Survey and sold at backpacking and map stores. You would follow the same instructions as above, only instead of numbered lines (1, 2, 3, etc.), you would write down the elevation (height above sea level) of the specific contours (e.g., 10', 20', 30', etc., as in the example to the left).

Figure 4-5. Construction of a topographic profile. Figure from the U.S. Geological Survey.

Exercise 4E: Making a Geologic Map

To understand what a geologic map shows, you will make a simplified geologic map for the area near SP Crater, north of Flagstaff, Arizona. On the side counter are boxes containing several rock samples from the area of SP Crater. You should examine and quickly identify each rock type.

In the very back of the worksheet is a black and white version of a satellite image of the area near SP Crater (***Worksheet 4E-1***). For this exercise, we will say that there are only three different map units: (1) the light-colored area, (2) the very dark lava flow, and (3) everything else. Use your identifications of the rock samples to help you decide what rock types to assign to each area. There are also faults in the area (fairly straight features), so identify likely positions of faults.

On ***Worksheet 4E-1***, draw the general boundaries between the different rock units with dark lines. Show the fault with an even darker, thicker line. You do not need to be too precise because we want this exercise to be brief. Label your rock units 1, 2, and 3. It does not matter which one is 1, which one is 2, etc, just number them in any order.

Fill in the simple legend for your map on the bottom of ***Worksheet 4E-1***. That is, write the name of each rock unit next to a box in the legend.

Box 4-1. Topographic Maps

Topographic maps are a way to depict the three-dimensional physical features of the land's surface on a two-dimensional sheet of paper, through the use of contour lines. A topographic map is drawn to scale, permitting distances, elevations, directions, and areas to be accurately measured. Specific symbols are used on topographic maps to designate both cultural and natural features. These symbols are explained in the *Topographic and Geologic Map Symbols*, included at the end of these instructions. Topographic maps are valuable tools for geological studies and for engineers involved in all types of construction, including planning and road building. They are also used by hikers, campers, and others interested in the location of features and the local terrain. Geologic maps, which show the distribution of different types and ages of rocks, are generally plotted on a topographic base map.

Contour Lines

On a topographic map, the third dimension, the dimension of height (or elevation), is shown using contour lines. A contour line is an imaginary line on the surface of the Earth that connects all points on the map having the same elevation above sea level. The contour interval is the vertical distance between each consecutive contour line. For example, a 40-foot contour interval means that the vertical distance from one contour to the next is 40 feet. On most topographic maps, every fifth contour, called an *index contour*, is shown with a darker line than the other contour lines and is generally labeled with a number indicating the elevation above sea level.

Tips for Reading Topographic Maps

- Determine the scale and contour interval of the map.
- Every point on a contour line has the same elevation. In other words, contour lines connect points of equal elevation.
- Dashed contour lines represent one-half of the contour interval (e.g., 10-foot dashed contours in a map with a 20-foot contour interval). They are added in areas of low relief to increase detail.
- Elevations on one side of the line are higher than elevations on the other side of the line.
- The direction of slope is perpendicular to any contour. Since rivers and streams flow downhill, they also give the direction that the land slopes and indicate which areas are high versus those that are low.
- Widely spaced contour lines represent gentle slopes; closely spaced contour lines indicate steep slopes.
- Contour lines do not cross or divide, except at overhanging cliffs. Contour lines that appear to run together, merge, or disappear are actually stacked one on top of the other and represent a cliff or very steep slope.
- There will be a matching set of contour lines on each side of a stream. Contour lines that cross stream valleys form a "V" pointing upstream.
- Concentric, closed contour lines represent a hill.
- Closed depressions (representing basins with no outlet) are shown by closed contours with hachures (short lines) that point inward toward the depression.

Box 4-2. Locating Yourself on a Topographic Map

- The key is to match a feature, such as a hill or cliff, you see in the landscape to its equivalent on the topographic map. If they are indeed the same feature, then they should have the same size, shape, steepness, and orientation (e.g., if a ridge runs in a north-south direction, it should appear on the map with the same orientation).
- Begin with the most distinctive features, such as a prominent peak, a mountain with two peaks, a steep cliff, or an unusually shaped hill. Any distinctive feature will work – the more distinctive the better.
- As you compare a landscape feature with its suspected equivalent on the map, pay attention to the smaller scale details on the feature (e.g., a small flat terrace on the south side of the hill).
- Compare the landscape surrounding a feature with what you see on the map. For example, two different hills in the landscape may be similar in size and shape, and therefore hard to tell apart, except one hill is just south of a larger mountain whereas the other hill is surrounded by a flat plain.
- A place where a feature, such as a stream, ridge, or cliff, changes direction is especially useful. For example, a north-flowing stream may abruptly turn east for a short segment and then bend back toward the north, and this should be a distinctive place on both the landscape and map.
- Places where two features join, diverge, or cross are also distinctive, such as where two streams join, one ridge splits into two ridges, or a stream crosses a cliff (like in a waterfall).
- Once you have tentatively matched a landscape feature with its equivalent on the map, test this conclusion by using the map to predict what other landscape features should be visible nearby. For instance, you could look at the map and say “If this is that hill, then there should be a smaller hill just to the west of it.” Do the opposite too, by looking at the landscape and predicting what you should see on the map (e.g., “That ridge has a small stream to the west, so let’s see if there is one on the map.”).
- This sequence of making observations, arriving at tentative conclusions, making predictions based on those conclusions, and testing those predictions is the most common way of doing science. As in science, its best to keep an open mind and remember that any conclusions you reach about locating yourself on a topographic map are tentative until tested sufficiently so that there is a small likelihood of being wrong.

Box 4-3. Elevation, Relief, Slope, and the Angle of Repose

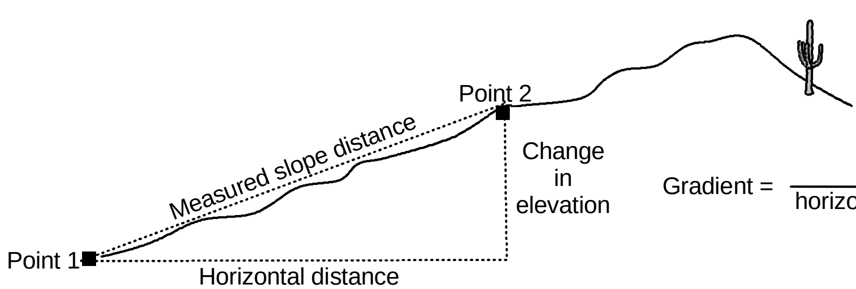
Elevation and Relief

In addition to wanting to know and measure directions horizontally, we may be interested in how rugged an area is and how much we would have to climb to reach the top of a hill. **Elevation** refers to the vertical height of a point above sea level. It is typically measured in feet or meters. When areas are surveyed during the construction of a topographic map, the precise elevations of several points are accurately measured. This procedure provides a reference system of known elevations for use by other surveyors and in drawing contour lines on the topographic map. Surveyed locations are called **benchmarks** and their positions are shown on most topographic maps with the letters “B.M.” The number beside this symbol lists the surveyed elevation, generally in feet. The elevation of points that do not fall directly on contour lines on a topographic map may be estimated by *interpolating* between the two adjacent contours. For example, a point on the ground situated midway between 640' and 660' contour lines would likely have an elevation of approximately 650'. In contrast, a point located very near to the 660' contour line would more likely have an elevation of 658' or 659'.

Relief is the difference in elevation between two points. It is easily calculated by subtracting the lowest elevation from the highest elevation in an area. If a mountain, for example, has an elevation of 8,000 feet and an adjacent valley has an elevation of 3,000 feet, we would say the relief between the two is 5,000 feet. The maximum relief on a topographic map is the difference in elevation between the highest and lowest points on the map. Relief is most commonly calculated when you are trying to determine how much elevation you will have to gain on a hike to the top of a mountain.

Slopes, Gradients, and the Angle of Repose

We generally think of **slope** in the context of hillsides: a steep slope versus a gentle slope. The steepness of a slope controls many geologic processes, such as landsliding, and has major land-use implications, including slope stability and whether a slope efficiently drains rainfall or becomes a swamp. The steepness of a slope can be expressed as an angle, ranging from 0° for a horizontal surface to 90° for a vertical cliff; most natural slopes are 30° or less. Slope can also be expressed as a **gradient**, which is the ratio between the elevation change of the slope and the horizontal length over which the change occurs. In algebra terms, it is the *rise* over the *run*. For example, if a slope drops 10 meters over a distance of 100 meters, it has a gradient of 0.1 (i.e., 10/100). On highway signs, this number is multiplied by 100 to convert it to a percent, and written as “% grade”. A road that drops 5 meters in a distance of 100 meters has a gradient of 0.05 (5/100), or a 5% grade (5/100 × 100%). Highway grades are rarely more than 8%.



Gradient = $\frac{\text{change in elevation}}{\text{horizontal distance between points}}$

♦

♦ **Figure B-2.** Calculation of gradient from a topographic profile. The profile above is an example profile drawn from a topographic map, which has designated the elevations of Points 1 and 2. To determine gradient, simply divide the change in elevation between the two points found on your topographic map by their horizontal distance. That's it!

Gradient is commonly also expressed as the ratio of two different units of measurement, such as feet/mile. In this case, the elevation difference of the slope (the rise) is measured in feet or meters, and the horizontal length of the slope (the run) is measured in kilometers or miles. For example, if a slope drops 30 meters vertically in one kilometer, it has a gradient of 30 meters/kilometer. This type of gradient is also used to convey how steep a stream or river is.

Gradient, for either a slope or river, can be calculated from a topographic map via the following:

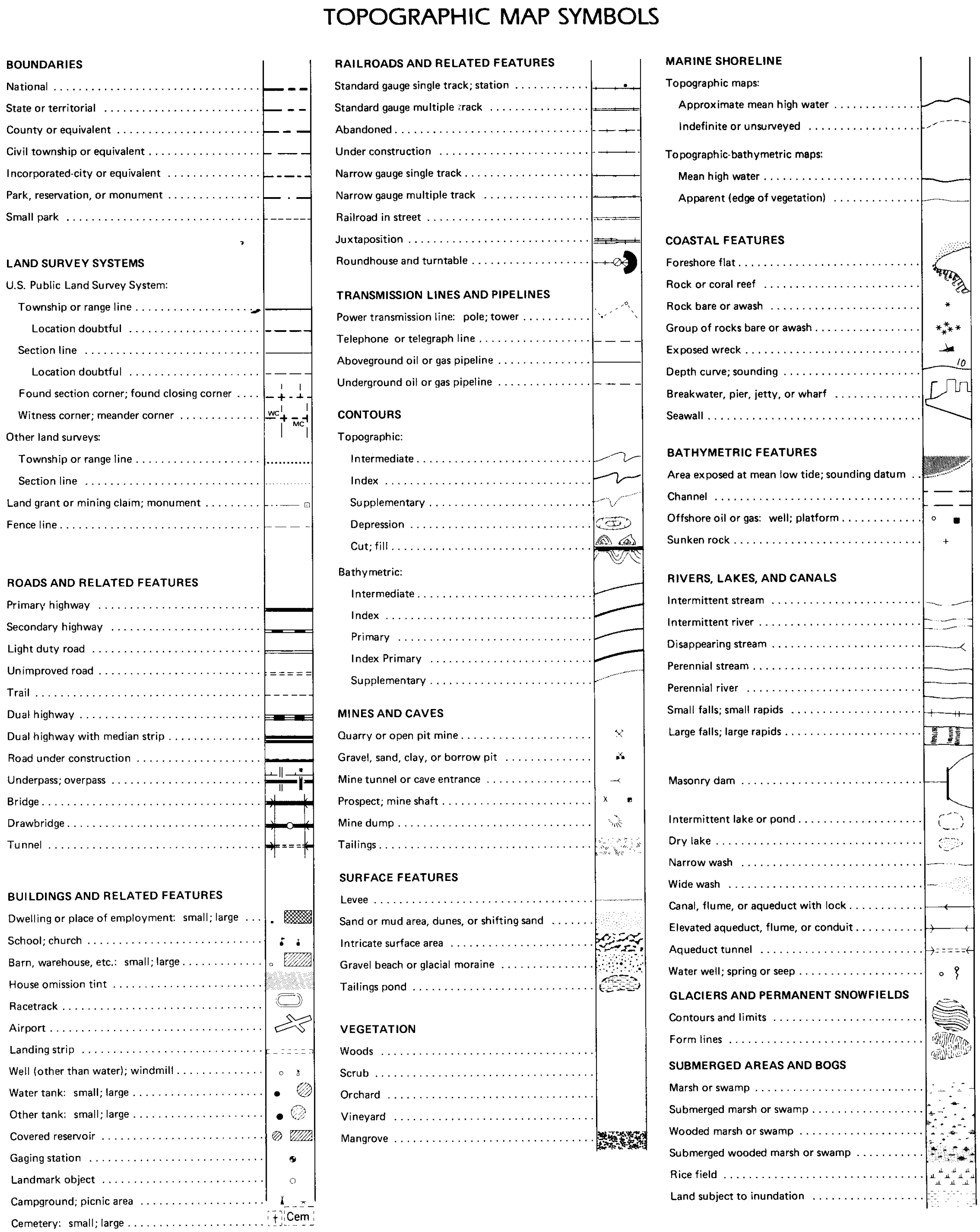
- Say you are interested in the gradient between two points that are 4 centimeters apart on a 1:50,000 map, with an elevation difference of 300 meters.
- Convert the total number of centimeters on the map into meters on the ground. On a 1:50,000 map, one centimeter on the map equals 50,000 centimeters on the ground, so 4 centimeters equal 200,000 centimeters (4 cm x 50,000=200,000 cm).
- Since there are 100 cm in a meter, simply divide 200,000 cm by 100 to convert the centimeters into meters. This gives a result of 2,000 meters (or 2 kilometers, since there are 1,000 meters in a kilometer).
- The equation for gradient is:

$$\text{Gradient} = \frac{\text{change in elevation between points (m)}}{\text{horizontal distance between points (m)}} = \frac{300\ \text{m}}{2{,}000\ \text{m}} = 0.15$$

For a gradient of 0.15, this means that for each 1,000 meters (kilometer) traveled on the ground, the slope increases or drops 150 meters in elevation. Be careful when extending gradients too far from where you calculated it. If there is no observed change in the spacing of contours lines, then the gradient of the slope has not changed much. However, if the spacing between contour lines changes noticeably, this indicates that the gradient has also changed.

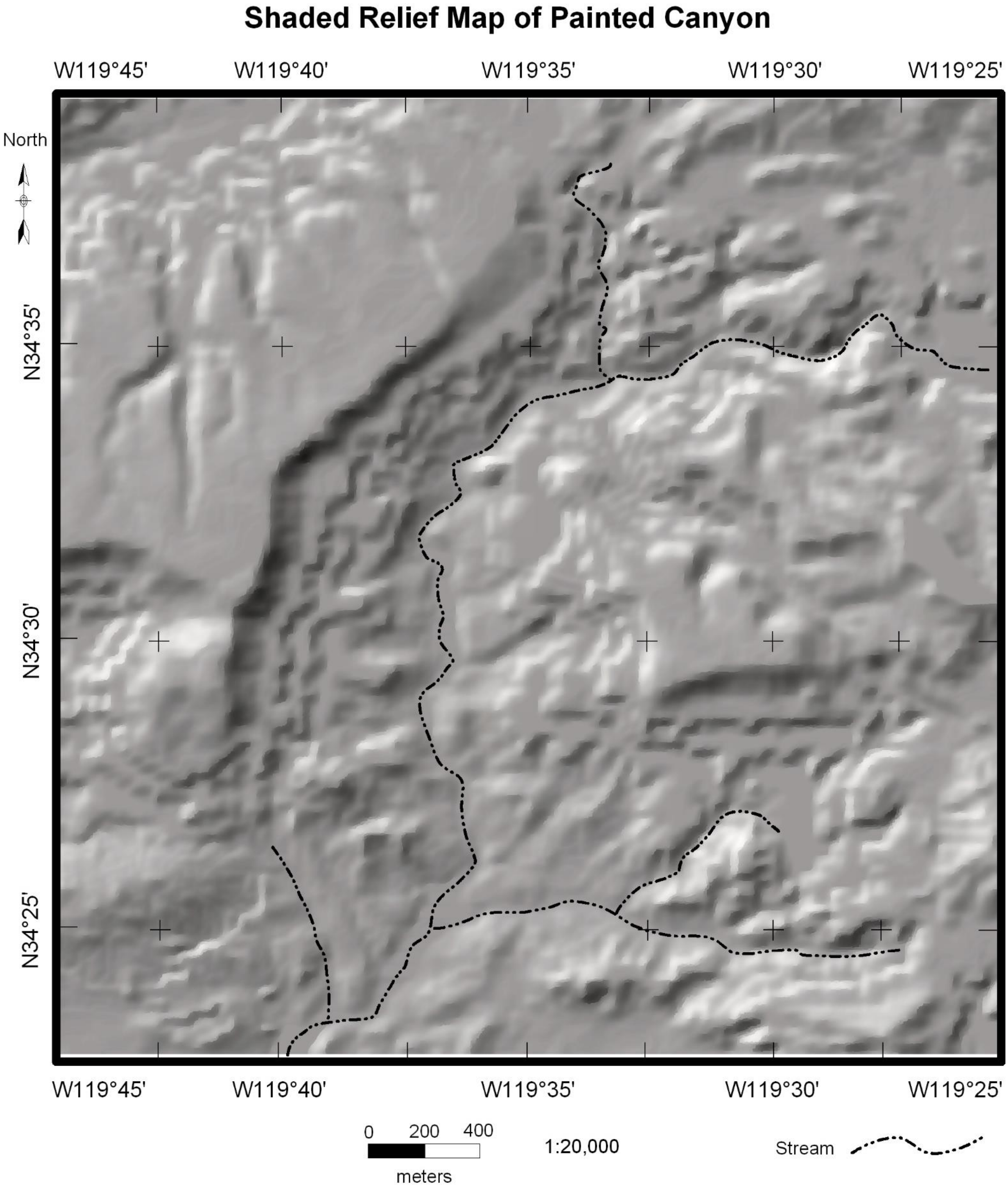
The importance of slopes and their angles is obvious when you see pictures of houses sliding into the ocean along the California coast. It's related to what happens when you try to walk up a sand dune. There is a maximum slope, or angle, at which a pile of loose material remains stable, called the **angle of repose**. The angle of repose of natural slopes is fairly constant, between 25º and 40º, but depends upon the size of the individual particles, their angularity, the degree of sorting, and whether they are wet or dry. Larger, more angular particles, such as gravel, tend to form slopes with steeper angles of repose than those of finer particles. If a slope is at its stable angle of repose, and some process removes material from the base of the slope, then the loose material up the slope will slump down to fill in the hole and reestablish the stable angle. If your house is built on this slope, it may come down the hill with the rest of the material. This is what happens in the California example, where waves undercut the base of a slope and the slope just doesn't like it! The angle of repose is expressed in **talus slopes**, where loose rocks and sand accumulate on a slope with a ~30° angle beneath cliffs, and also on the sides of cinder (scoria) cones.

Box 4-4. Topographic and Geologic Map Symbols

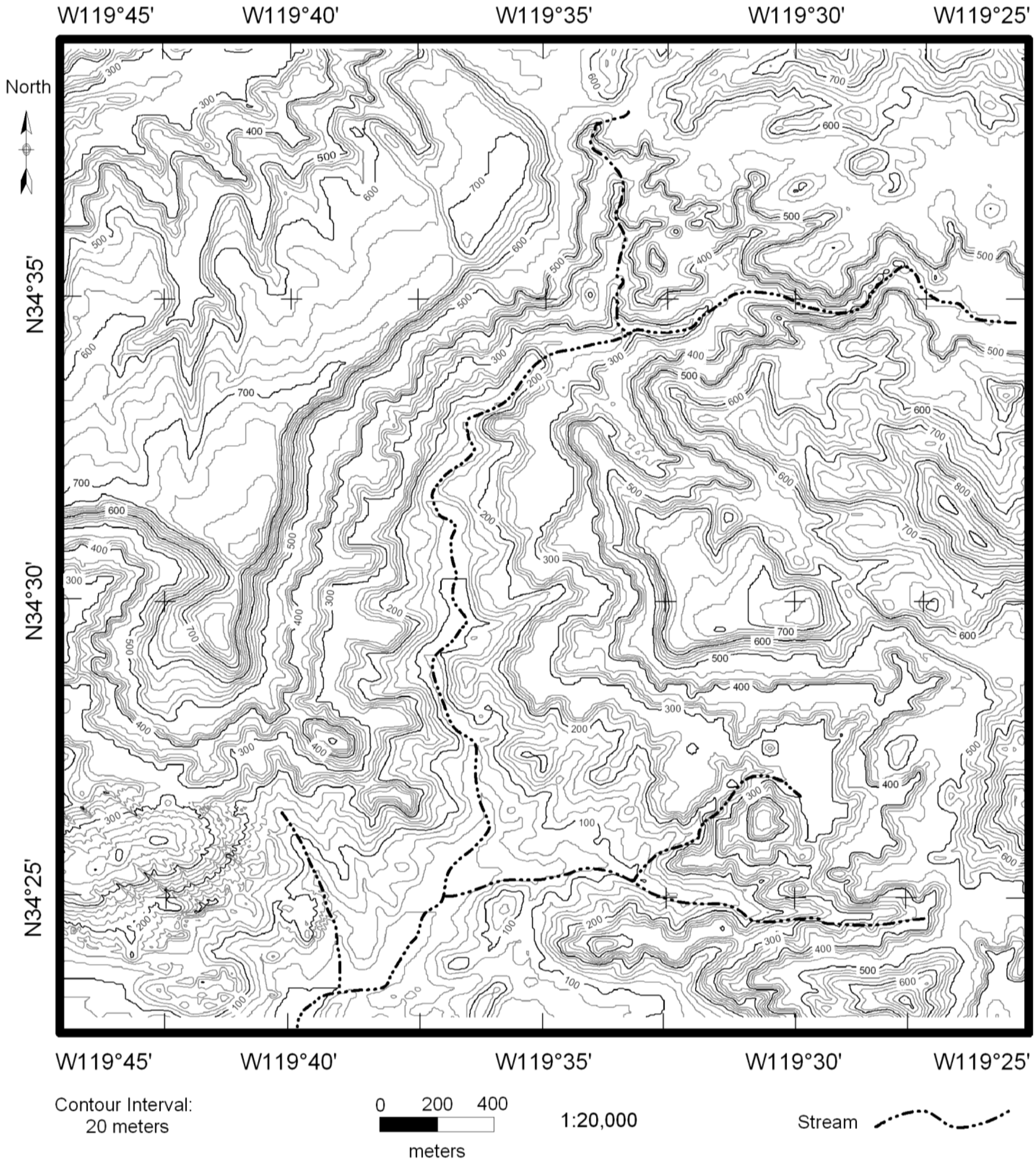


Source: U.S. Geological Survey

Shaded relief map of Painted Canyon illuminated from the northwest.



Topographic Map of Painted Canyon



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Topographic Map of Painted Canyon

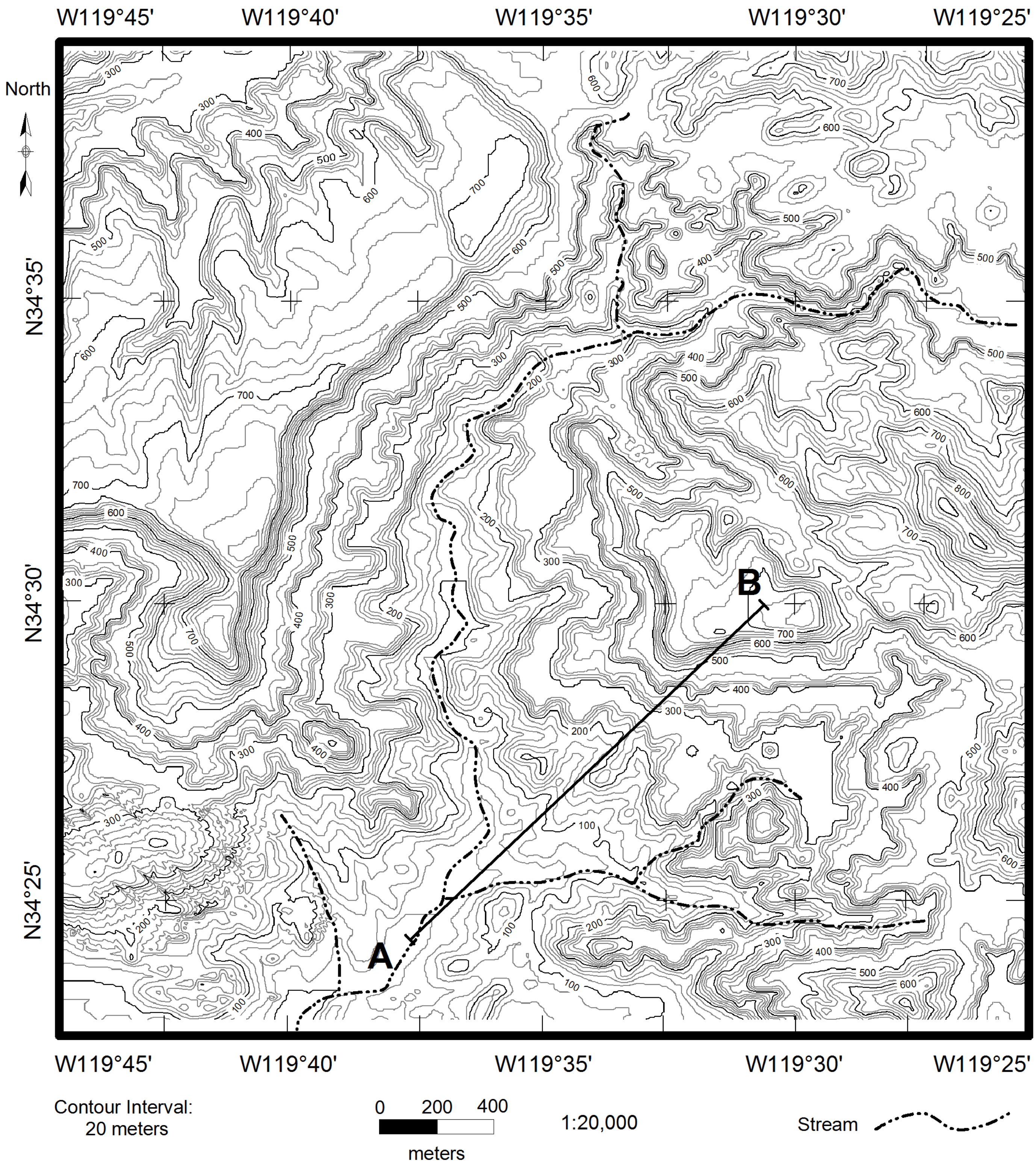

Figure Map 4D-1 See the worksheet for the profile grid from A-B**.**

Figure 4E-1. Satellite image of SP Crater, SP lava flow, and surrounding area.