EXERCISE 1

TOPOGRAPHIC MAPS

ASSIGNMENT: Before this lab and all successive labs, read the material in the Introduction and Background Information, and look through the lab exercise to see what you will be doing and what materials you may need. You will need a ruler, a protractor, two colored pencils, and a calculator to do this exercise.

INTRODUCTION

The purpose of this exercise is to familiarize you with graphic representations of the Earth's surface - primarily maps. Simple line maps show the spatial relationship of major natural features like mountain ranges and rivers, as well as political subdivisions like countries and states. Topographic maps show more detailed information on the nature of the Earth's surface and provide quantitative information about elevations, distances, and steepness of terrain. Exercises on contouring will provide you with an ability to understand and "read" topographic maps, and you will appreciate the difference in information content of different scales of maps. The maps will also familiarize you with the area around Golden.

BACKGROUND INFORMATION

TOPOGRAPHIC MAPS

Topographic maps are graphic representations of selected features of the Earth's surface plotted to definite scales. The distinguishing aspect of topographic maps is the portrayal of the shape and elevation of the terrain. Such maps record in convenient, readable form, the physical characteristics of the terrain as determined by precise engineering surveys and measurements.

Topographic maps have many uses as basic tools for planning and executing projects; they are an essential part of geologic and hydrologic research, of mineral investigations, and of studies on the quantity and quality of water. They greatly facilitate the study and application of flood control, soil conservation, and reforestation. Topographic maps are of prime importance in planning highways, dams, industrial plants, and countless other types of construction. Intelligent and efficient development of natural resources depends on the availability of adequate topographic mapping. Map users include people who have discovered the advantages of topographic maps in the pursuit of outdoor activities such as hunting, fishing, skiing, and hiking.

Map Scale. Topographic maps are classified by scale. Map scale defines the relationship between the size of features as shown on the map compared with their size on the Earth's surface. In this respect, a map is a scale model of the land surface, similar to a scale-model airplane, train, or tyrannosaur.

Scale is generally stated as a ratio or fraction - 1:24,000 or 1/24,000. The numerator represents map distance, and the denominator, a large number, represents horizontal ground distance. Thus the scale 1:24,000 states that any unit, such as 1 inch or 1 cm on the map, represents 24,000 of the same units on the ground. Refer to the table below for a comparison of some of the more commonly used scales.

1Descriptive text abstracted from USGS publications (Thompson, 1987, and USGS, 1970).
<table>
<thead>
<tr>
<th>Scale</th>
<th>1 inch represents</th>
<th>1 cm represents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:500,000</td>
<td>8 miles (approx.)</td>
<td>5 kilometers</td>
</tr>
<tr>
<td>1:250,000</td>
<td>4 miles (approx.)</td>
<td>2.5 km</td>
</tr>
<tr>
<td>1:100,000</td>
<td>1.6 miles (approx.)</td>
<td>1.0 km</td>
</tr>
<tr>
<td>1:24,000</td>
<td>2,000 feet</td>
<td>240 meters</td>
</tr>
</tbody>
</table>

**Large-scale maps**, such as the 1:24,000-scale maps, are especially useful for highly developed areas or rural areas where detailed information is needed for engineering planning or similar purposes.

**Intermediate-scale maps**, ranging in scale from 1:50,000 to 1:100,000, cover larger areas and are especially suited for land management and planning.

**Small-scale maps**, such as those made at scales of 1:250,000, 1:500,000, and 1:1,000,000, cover very large areas on a single sheet and are useful for comprehensive views of extensive projects or for regional planning.

**Topographic Quadrangle Maps.** In the United States the best known topographic maps are the U.S. Geological Survey quadrangle series, which range in scale from 1:24,000 to 1:250,000. The basic series are listed below:

- 7 1/2-minute quadrangle (1:24,000 scale)
- 15-minute quadrangle (1:62,500 scale)
- Alaska (1:63,360 scale)
- 1-degree quadrangle (1:100,000 scale)
- 2-degree quadrangle (1:250,000 scale)
- National Park (varying scales)
- State (1:500,000 and 1:1,000,000 scales)
- United States (varying scales)
- International Map of the World (1:1,000,000 scale)

The most popular topo quadrangle maps in use today are shown in the figure.

**LOCATING A POSITION ON A MAP**

**Latitude and Longitude**

The Earth is a three dimensional sphere, but its surface is two dimensional. By overlaying an imaginary grid on the Earth’s surface, and position can be uniquely identified by a set of two numbers: latitude and longitude. In this grid system, the Earth’s equator is used as a line of reference for the lines of latitude (a.k.a. parallels), which form east-west trending circles around the globe. The number associated with the line of latitude can be thought of as the minimum angle that can be formed between a line from the center of the Earth to that line of latitude, and a line from the center of the Earth to the equator. Given a moments thought, it should be obvious that the largest value a latitudinal position can have is 90º, which exists an either the North or South Pole. It should now also be obvious that in this system we must designate between lines of latitude to the north of the equator, and those to the south.

The equator of the earth is a unique and easily defined reference line for lines of latitude. Lines of longitude trend north-south, but there is no unique reference line in this system. It has been agreed that a line that runs directly through an observatory in Greenwich, England is the reference line for longitude. It is referred to as the Prime Meridian or Greenwich Meridian. To determine the longitudinal value for a point on Earth, you would observe the Earth from directly above one of
the poles, and find the angle between the reference line and a line running from pole to pole through your point. In this system we must declare if our point is to the east or west of the reference line. The largest number possible for longitude is 180º (like the reference line, the 180º has no east or west designation, and when the 0º and 180º lines are joined they make a complete great circle around the earth going through both poles.

We will now use the lat-lon system to designate a position on Earth: your lab room. The lab rooms in Berthoud Hall are all approximately at 39º 45’ 01.15” N; 105º 13’ 20.22” W. We can tell the first number is the latitude either because it is the only one less that 90º (which doesn’t always work for us) or because it is given a north designation. Our labs are a bit less that half way from the equator to the North Pole, and are a bit more than a quarter turn of the Earth west of the Prime Meridian. Both these numbers are given in degrees (º), minutes (’), and seconds (”). There are 360º in a full circle, 60’ in each degree, and 60” in each minute, which allows for very accurate measurements. Now we can better understand why the 1:24000 scale map mentioned above is also called a 7 ½-minute quadrangle; it covers 7.5’ of latitude, and 7.5’ of longitude.

**Public Land Survey System**

In the United States, there is another method of locating a position on a map. According to rules devised by Thomas Jefferson, and originally set into law by Congress in 1785, public land at that time was subdivided and surveyed into townships, which are squares, six miles on a side, with boundaries running north-south and east-west. Townships are further subdivided into 36 one-mile-square sections.

Each township is identified by its position within a grid of north-south range lines and east-west township lines. Townships run north and south of a reference baseline, while ranges run east and west of a principal meridian, as illustrated below. The shaded township is identified as T 2 S, R 3 W.

**Which way is North?**

At the bottom of every topographic map is a symbol that looks like this: The star represents true north, while the MN refers to magnetic north. A compass’ north needle will point to the magnetic north, which for most places on Earth is not the same as true north because the Earth’s magnetic dipole is not in alignment with the rotational axis of the Earth. The number (14º in this case) is the angle made between true north and the direction a compass needle will point in the given map area, and is known as the “magnetic declination”. The magnetic declination for Golden is currently 9º 44’ E of north, and in recent years has been drifting 0º 8’ W/year.

**Contour Lines**
Contour lines are the principal means used to show the shape and elevation of the land surface. A contour line is a line of equal elevation. A contour may be defined as an imaginary line on the ground, every point of which is at the same elevation above sea level. A contour is the line traced by the intersection of a level surface with the ground. A series of contours is traced by a series of level surfaces, a different contour for each elevation.

Each contour line represents a definite ground elevation measured from mean sea level, and the contour interval is the difference in elevation between adjacent contours. The contour interval, together with the spacing of the contour lines on the map, indicates the slope of the ground. On steep slopes the lines are spaced more closely than on gentle slopes.

The basic characteristics of contours are illustrated in the figure, which shows a perspective view of a river valley and adjoining hills, along with the same features shown on a topographic map.

**Reading Topo Maps**

Learning to read topo maps is mainly learning to interpret contour line patterns. For example, a common pattern is the Λ pattern (figure, right), which is characteristic of a stream valley, and the apex of the Λ always points upstream.

Closed contour lines (figure, left) indicate hills (one can walk a horizontal path and return to the starting point - that is, one can "contour the hill", or go around it without climbing or descending). Closed contour lines with hachure lines indicate closed depressions.

Because the contour interval is constant on any topo map, the relative spacing of the contours indicates the steepness of a slope. Closely spaced contours mean elevation is gained in a relatively short horizontal distance - the slope is steep - whereas widely spaced contours indicate the same elevation is gained over a broader distance, with a gentler slope. The hill in the above figure is asymmetrical; it has a steep slope on the northwest side and a gentle slope on the southeast side. Slope angles can be calculated easily as follows: \( \text{Slope (°)} = \tan^{-1}(\text{rise/run}) \)
CONTOURING

Figure 1 is a map of surveyed elevations. The dots represent data points of elevation above sea level, in feet.

1. Draw the topographic contours, using a contour interval of 20 ft. You may choose to mark every datum between two contours with the same symbol or color and then group them together as you draw your contours. It is also recommended to use a pencil to draw in contours as even the best of us can make mistakes.

2. Describe the landform. Is it symmetrical?

3. Make a line across the map with a northwest orientation. Label the northwest end of the line as A and the southeast end of the line A’.

4. In the space below, draw a line the same length as your A-A’ line, then add a perpendicular elevation line with no scale.

5. Sketch what the landform looks like in cross-section on this A-A’ coordinate system.

Figure 1--Elevation data points.
Figure 2 — Topographic map of the Golden, Colorado, area. Two different 7½’ maps have been joined.
MAP USE

Figure 2 is a topographic map of the Golden area.

1. Find Berthoud Hall, circle it, and label it BH.

2. What is the latitude of Berthoud Hall? ____________________

3. Using the Public Land Survey system, describe the location of Berthoud Hall:

The topographic map in Figure 2 was created by joining adjacent parts of the Golden and Morrison 7.5’ quadrangle maps. The two maps were originally published with different contour intervals, which shows on Figure 2 as a change in contour density.

4. Label the line along which these two quads are joined with a "J" at each end.

5. Determine the contour intervals (CI) of each of these two maps:

   Golden Quad (north) CI ____________
   Morrison Quad (south) CI ____________

Relief is used to describe the elevation differences in an area; an area of rugged terrain has high relief, whereas a fairly flat area has low relief. Relief, then, is the difference between the highest and lowest points in an area.

6. Find the highest point in the area shown by the map, label it B, and determine its elevation:

   Elevation of point B ________________

7. Find the lowest point on the map and label it B’. This would be where Clear Creek leaves the map area (note: because water features are shown on the original topo map in blue, which does not photocopy well, it is difficult to find this point with certainty; the elevation here is about 5600 ft).

8. What is the topographic relief in this area? Relief ________________

Topo maps are useful for determining distances between points and compass directions, or bearings:

9. Find the conical hill in the NE 1/4, Sec. 28, T 3 S, R 70 W, label it C, and measure the distance from the top of this hill to the top of Mt. Zion.

   Distance ____________ ft, __________ mi, __________ m, __________ km.

Because topo maps represent true distances, and because they provide elevation information, they can also be used to calculate slope angles, as illustrated:

10. On the topo map, draw a short line just below the M in the direction of the maximum slope angle, that is, a line approximately perpendicular to the contour lines. Pick a contour near the top of this line and another near the bottom, measure the horizontal distance between the contours, and calculate the true slope angle.

   Calculated slope angle ____________.

11. Calculate the percent grade of the land surface you measured in question 10.

   (Slope = vertical distance/ horizontal x 100%)

   How much elevation did you gain when you walked from the campus up to the M?
VISUALIZING MAP FEATURES

(Use the topographic map of the Green Mountain area for this part of the lab)

12. Draw a solid line (or use a color) along the 6600’ contour around Green Mountain.

13. Draw a dashed line (or use a different color) along the 6400’ contour around Green Mountain.

14. As the elevation on the mountain increases, does the area inside the contour increase or decrease?

15. Draw dark lines (or blue lines) along the major drainages that flow down off Green Mountain.

16. Label the main ridges that extend out from Green Mountain with the letter “R”.

17. Contour lines go _____ relative to the top of the mountain as they show drainages (valleys) and _____ from the top of the mountain as they show ridges. (use the words “inwards” and “outwards”)

   How are the contour line “shapes” different for valleys relative to ridges?

   Draw examples of each.

18. Is the top of Green Mountain gentle or steep relative to the sides? How can you tell?

19. Use the section graph at the bottom of the map sheet to construct a topographic profile across Green Mountain along section line A-A’. (put west on the left as it is on the map)

   Make light horizontal lines across the graph at 200’ intervals between 5800 and 6800 feet.
   Put the edge of a sheet of paper along A-A’, marking the ends of the profile line on the paper.
   Mark where the profile crosses each dark contour and label the marks.
   Use this sheet to mark off on the graph where each contour is crossed.
   Connect the marks to make a smooth topographic profile.
   Use the spacing of the light contour lines to add realism and detail to your profile.

   Note that the scale on your profile is vertical = horizontal.

20. If you made the topographic profile at vertical = 2x horizontal (vertical exaggeration), would the mountain slopes look steeper or more gentle?

21. Look at the feature labeled “HOGBACK” or Dinosaur Ridge. Is the top of this mountain “sharper” or more gentle than the top of Green Mountain. Sketch a topographic profile of the HOGBACK below. (not to scale)
22. Topographic maps are great for plotting out the best routes for hiking or for climbing peaks.

If you were at point “X” in Mount Vernon Canyon, what would be the best (easiest) route to follow if you wanted to get to the top of Mount Morrison? Show your route with a dashed line.

What is the distance between “X” and Mount Morrison “as the crow flies”?

What is the total distance you would travel on your route?

What is the total amount of elevation you would gain?

Why did you pick this route instead of the shortest route?

REFERENCES


Availability of Topographic Maps

Topographic maps are housed in the Map Room of Lakes Library, in the southwest corner of the lowest level. They are available for use in the library, and some can be checked out.

If you want to buy your own topo maps for hiking, camping, etc., you should visit one of the more than 70 ESIC’s (Earth Science Information Centers) in the U.S. or call 1-800-USA-MAPS. In the Denver Metro area, maps can be purchased over-the-counter at USGS Map Sales, Building 810, Denver Federal Center, generally open from 8 a.m. to 4 p.m., tel. (303) 236-7477.