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Using Topographic Maps to Generate Topographic Profiles

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Overview

Source: Laboratory of Alan Lester - University of Colorado Boulder

Topographic maps are "plan-view" representations of Earth's three-dimensional surface. They are a standard type of map-view that provides an overhead, or aerial, perspective.

Among the defining features of a topographic map are the contour lines that indicate locations of constant elevation. The elevation interval between the contour lines is dependent on the level of detail provided by the map and the kind of topography present. For example, regions with significant topographic variation might require contour lines separated by 40-100 ft., whereas generally flat-lying regions with little topographic variation might have more broadly separated 10-20 ft. contours.

To an experienced user of such maps, the patterns made by the topographic lines are representative of various landform patterns, such as ridges, valleys, hills, and plateaus.

Principles

Although modern three-dimensional imagery (*e.g.* digital elevation models, Google Earth) can be useful as a means to get a rapid and general impression of a landscape, these images are subject to distortion and cannot be used to extract quantitative elevation data. In contrast, a topographic map can provide a distortion-free source of information regarding altitudes for discrete points over the entire map area.

The ability to extract dependable elevation data for any point on the topographic map allows for the construction of topographic profiles. These are cross-sectional views (perpendicular to the standard plan-view or map-view) that define a continuous series of elevations along a line, connecting two points on the map. The topographic profile is a graph of elevation (y-axis) versus distance (x-axis) between the two defined points on the topographic map. This graphical profile allows one to effectively see the land surface from an "edge-on" view that shows how the land surface rises and falls along a hypothetical line, joining two points on the map. The perspective of the topographic profile is very useful; it provides a starting point for making geologic cross-sections that project rock structures or layers into the subsurface.

Procedure

1. Obtain a topographic map.
2. Establish a line between two specified points on the map. Call these points, A-A', or X-X', or Y-Y'.
3. Lay the edge of a paper strip along the cross-section line, marking the two points, A-A', with tick marks.
4. Place a tick mark where each of the contour lines intersects the line of the cross-section. Add notations that indicate the elevations of those contour lines.
 1. If there is substantial topographic variation along the chosen line, A-A', start by only marking the intersection of the line with the major contours. The major contours (also called index contours) are those that show up on the map as bold, slightly heavier lines.
 1. For example, major contours on a 7.5-minute quadrangle map are typically used to indicate 200 ft. intervals on the map, with the standard contour lines representing 40 ft. intervals. This means that between every major contour, there are 4 standard contours (representing 5 steps in elevation to move from one major contour to the next).
 2. Along certain portions of the cross-section line, there may be steep topographic variation, and therefore, closely-spaced contour lines. Here, mark only the major contours. Where there is little topographic variation, mark all contours (where they intersect the cross-section line).
5. Set the paper with the tick marks along the x-axis of a piece of graph paper. Transfer the elevation marks onto the y-axis with a dot.
 1. This generates a graph of elevation (y-axis) versus distance along the A-A' line.
 2. The scale of the x-axis is defined by the map itself. The scale of the y-axis can be chosen to be equivalent to the map scale (resulting in no vertical exaggeration), or it can be chosen such that the small elevation variations are effectively "stretched out" (resulting in vertical exaggeration).
6. Smooth the profile by connecting the dots, recognizing that most topographic variation in the real world does not exist in abrupt steps.

Results

Once properly smoothed and checked against the map itself (for elevation details between points), the resulting topographic profile is a representation of the highs and lows of a landscape, between the defined points.

When topographic profiles are used as a base for projections of geologic features into the subsurface, it's generally best to avoid vertical exaggeration - in other words, the horizontal and vertical axes should have the same scale. However, when there is very little vertical variation across the topographic profile line, it might be useful (in order to visualize topography) to have a different vertical scale, effectively stretching out the vertical topographic variations.

The degree of vertical exaggeration is equal to the vertical fractional scale divided by the horizontal fractional scale. For example, if one is using a typical U.S. Geological Survey topographic map with a horizontal scale of 1:24,000 (1 in. on the map represents 24,000 in. in the real world) and a chosen vertical scale of 1:24,00 (1 in. on the vertical scale represents 2,400 in. of vertical change), then the vertical exaggeration is simply $1/2,400$ divided by $1/24,000$ which equals 10X vertical exaggeration.

Some vertical exaggeration is often useful, particularly when the topographic profile is being used primarily to show the ruggedness of the terrain. As per the previous example, on a 1:24,000 map (the scale generally used on standard USGS 7.5-minute quadrangle maps), 1 in. on the lateral x-axis of the topographic profile represents 2,000 ft., and these maps (depending on latitude) are around 6 by 8 mi. in total (east-west versus north-south) dimension. But in many map regions, there is substantially less than 2,000 ft. (i.e., 1 in.) of vertical relief over the entire map area; therefore, a non-exaggerated profile shows very little variation on the y-axis, and an exaggerated profile may be desired.

For the purpose of making geologic cross-sections, where the main interest is to project rock layers into the subsurface (and less significance is given to the surficial topographic variation), it is best to use a non-exaggerated topographic profile as the base from which to make the projections. With a non-exaggerated profile, the rock layer dip-angles do not need to be modified. This is discussed in greater detail in the "Making a Geologic Cross Section" video.

Applications and Summary

A topographic profile provides a visual representation of the topographic highs and lows across a line segment on a map, from one point to another. Such profiles are used to evaluate the "ruggedness" of terrain, which is useful in assessing the difficulty of travel (driving, biking, or hiking as transportation modes for field-work) (**Figure 1**). Sometimes fieldwork requires making a transect through a region for the purpose of collecting samples or making geophysical measurements. A topographic profile can tell the field-scientist something about the difficulty and feasibility of such a traverse.

Nearly all topography on planet earth is a consequence of the interplay between uplift (whether generated by volcanism, tectonism, tidal forcing, impact, etc.) and erosion. As such, detailed analyses of topographic variations are a critical part of assessing geomorphic models related to terrain evolution. For example, if a geologist wants to know why a river or glacier system exhibits significant gradient variation along its course, topographic profiles are the primary means to quantify these changes (**Figure 2**). Topographic steps and variations can be used to indicate the relative resistance of rocks and soils to erosion; low areas being of greater susceptibility to erosion.

Topographic profiles are also the land-surface base for making geologic cross-sections (see video *Making a Geologic Cross Section*). A cross-section is a graphical projection of surface rock or soil layers into the subsurface. This side-view of the earth's interior is crucial to interpreting all kinds of geologic features. Geologists use cross-sectional views of the subsurface to interpret the location of ground-water reservoirs and flow regime, identify possible oil and gas pockets, and model mechanisms for rock deformation (folding and faulting).



Figure 1. An example of terrain that would require topographic evaluation. [Please click here to view a larger version of this figure.](#)



Figure 2. Deep, eroding glaciofluvial deposits alongside the Matanuska River, Alaska. [Please click here to view a larger version of this figure.](#)