4
Geomorphic Indices of Active Tectonics

INTRODUCTION

Morphometry is defined as quantitative measurement of landscape shape. At the simplest level, landforms can be characterized in terms of their size, elevation (maximum, minimum, or average), and slope. Quantitative measurements allow geomorphologists to objectively compare different landforms and to calculate less straightforward parameters (**geomorphic indices**) that may be useful for identifying a particular characteristic of an area—for example, its level of tectonic activity.

Some geomorphic indices have been developed as basic reconnaissance tools to identify areas experiencing rapid tectonic deformation [1]. This information is used for planning research to obtain detailed information about active tectonics. Other indices were developed to quantify description of landscape [2]. Geomorphic indices are particularly useful in tectonic studies because they can be used for rapid evaluation of large areas, and the necessary data often are obtained easily from topographic maps and aerial photographs [1]. Some of the geomorphic indices most useful in studies of active tectonics are:

- the hypsometric integral [2]
- drainage basin asymmetry [3, 4]
- stream length–gradient index [5]
- mountain front sinuosity (S_{mf} index) [6, 7]
- ratio of valley floor width to valley height (V_f index) [6, 7].

The results of several of the indices may also be combined, along with other information such as uplift rates, to produce **tectonic activity classes** [7], which are broad-based assessments of the relative degree of activity in an area.

HYPSOMETRIC CURVE AND HYPSOMETRIC INTEGRAL

The **hypsometric curve** describes the distribution of elevations across an area of land, from one drainage basin to the entire planet. The curve is created by plotting the proportion of total basin height (relative height) against the proportion of total basin area (relative area) (Figure 4.1) [2]. A hypsometric curve for a drainage basin on a uniform slope (Figure 4.2) illustrates how the curve is created. The drainage basin spans eight contour lines, numbered 1 to 8 on the figure. The total surface area of the basin *(A)* is the sum of the area between each pair of adjacent contour lines. The area *(a)* is the surface area within the basin above a given line of elevation *(h)*. The value of relative area *(a/A)* always varies from 1.0 at the lowest point in the basin ($h/H = 0.0$) to 0.0 at the highest point in the basin ($h/H = 1.0$).

A useful attribute of the hypsometric curve is that drainage basins of different sizes can be compared with each other because area and elevation are plotted as functions of total area and total elevation. That is, the hypsometric curve is independent of differences in basin size and relief [2]. As long as the topographic maps being used are of a sufficiently large scale to accurately characterize the basins being measured, there should be no effect of different scales.

A simple way to characterize the shape of the hypsometric curve for a given drainage basin is to calculate its **hypsometric integral**. The integral is
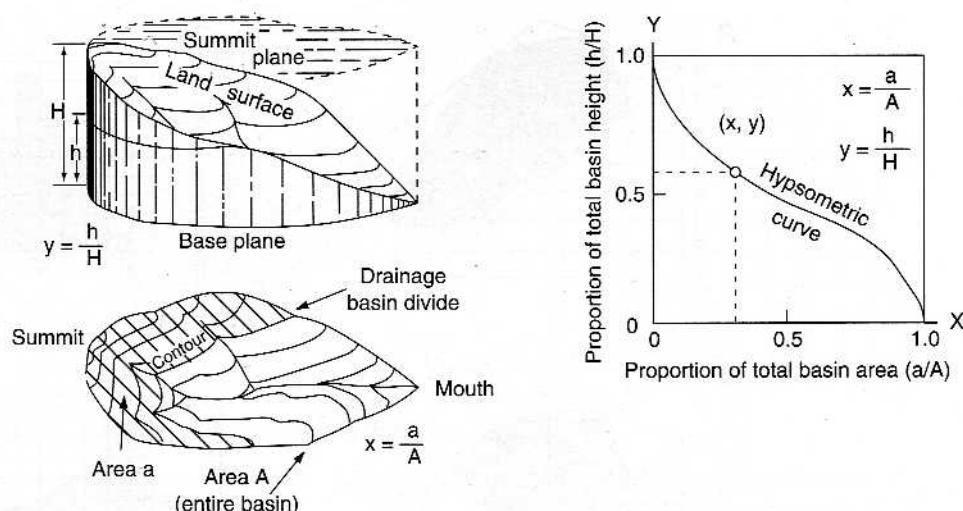
FIGURE 4.1
Hypothetical drainage basin showing how one point (x,y) on the hypsometric curve is derived. Plotting several other values (for different contours) of *a/A* and *h/H* allows the curve to be constructed.
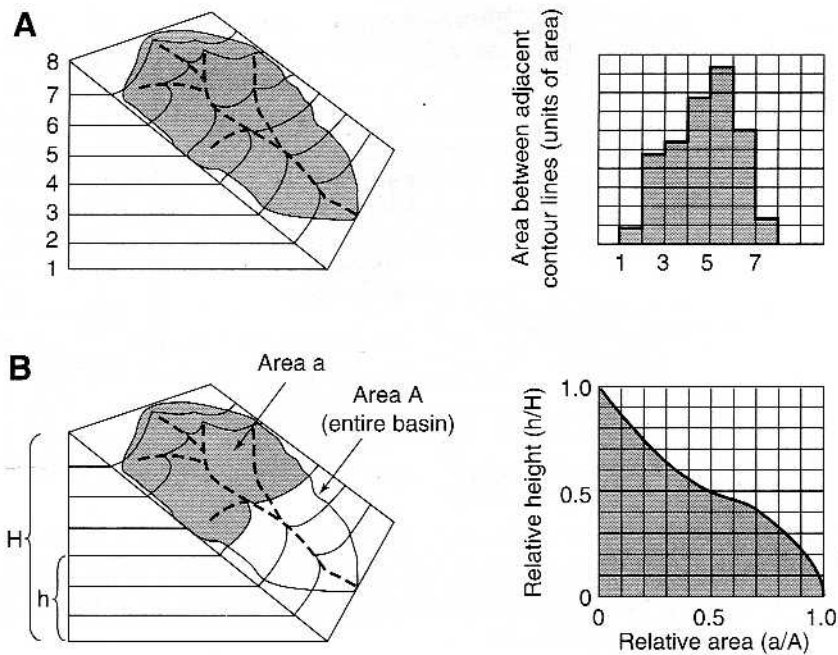(After Strahler, 1952 [2])

defined as the area under the hypsometric curve. One way to calculate the integral for a given curve is as follows [8, 9]:

$$\frac{\text{mean elevation} - \text{minimum elevation}}{\text{maximum elevation} - \text{minimum elevation}} \quad (4.1)$$

Thus only three values, easily obtained from a topographic map, are necessary to calculate the integral. Maximum and minimum elevations are read directly from the map. Mean elevation is obtained by point sampling (on a grid) of at least 50 values of elevation in the basin and calculating the mean [8], or by using Digital Elevation Models (DEMs). High values of the hypsometric integral indicate that most of the topography is high relative to the mean, such as a smooth upland surface cut by deeply incised streams. Intermediate to low values of the integral are associated with more evenly dissected drainage basins.

The relationship between the hypsometric integral and degree of dissection permits its use as an indicator of a landscape's stage in the cycle of erosion (see Chapter 2). The cycle of erosion describes the theoretical evolution of a landscape through several stages: a "youthful" stage characterized by deep incision and rugged relief, a "mature" stage where many geomorphic processes operate in approximate

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FIGURE 4.2
Idealized diagram showing how the hypsometric curve is determined. See text for further explanation.
(After Mayer, 1990 [9])

equilibrium, and an "old age" stage characterized by a landscape near base level with very subdued relief. A high hypsometric integral indicates a youthful topography (Figure 4.3A). An intermediate value of the hypsometric integral and a sigmoidal-shaped hypsometric curve indicate a mature stage of development (Figure 4.3B). Further development to the old-age stage will not change the value of the integral, unless high-standing erosional remnants are preserved (Figure 4.3C). However, more sophisticated numerical descriptions of the hypsometric curve that are sensitive to continued evolution of the topography are available [2, 9, 10]. In summary, hypsometric analysis remains a powerful tool for differentiating tectonically active from inactive regions. The calculation of hypsometric curves and integrals has become almost trivial with the advent of digital elevation models (DEMs) [11]. Hypsometry at continental and planetary scales is discussed in Chapter 9.

DRAINAGE BASIN ASYMMETRY

The geometry of stream networks can be described in several ways, both qualitatively and quantitatively. Where drainage develops in the presence of active