## The Use of Slope Distributions in Defining Physiographic Regions in Southern Indiana

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### Introduction

This paper reports an attempt at quantitatively characterizing the physiographic units of southern Indiana on the basis of their slope distributions. The data were derived from USDA soil survey maps and were analyzed using the distance function.

The original objective of this study was to use the distribution of slope of the land to define the boundaries between different physiographic units in Indiana. It was thought that each province would have its own characteristic slope distribution and that at the boundaries there would be a definitive break in the distributions to indicate the change from one province to another. As the study progressed, the objective was modified to that of evaluating the application of statistical techniques to slope data to see if this was a feasible method of quantitatively characterizing physiographic units and placing boundaries between them.

The study area consisted of Spencer, Perry, Crawford, Harrison, Floyd, and Clark counties in southern Indiana. Most of the southern physiographic regions of Indiana, from the Wabash Lowland west to the Scottsburg Lowland, are represented in this area. The Crawford Upland comprises the largest proportion of land in these counties and is the only province represented in all of the transects.

### Previous Work

The first attempt to subdivide Indiana on a physiographic basis was that of C. R. Dryer, who divided southern Indiana into a series of lowlands and uplands "bounded by relatively steep slopes or escarpments formed by the outcropping edges of the harder strata." (2) C. A. Malott found fault with several of Dryer's subdivisions and proposed his own scheme of physiographic regions (4) which is the definitive one used to this day, with minor modifications in northern Indiana by W. J. Wayne (9).

Malott divided southern Indiana into seven units which trend roughly north-south along the regional strike of the bedrock (Fig. 1). From east to west these units are: Dearborn Upland, Muscatatuck Regional Slope, Scottsburg Lowland, Norman Upland, Mitchell Plain, Crawford Upland, and Wabash Lowland. The devisions were made on the basis of unity of topographic condition, which Malott defined as the area's "state or condition with respect to relief, altitude, and the form, size, and relationship of the physical features present" (4). He states that this can be presented adequately only by a detailed topographic map. The differences in topographic condition between the physiographic provinces of southern Indiana are lithologically controlled, being influenced by the differential resistance of the sandstones, shales, and limestones present, so that the physiographic units roughly parallel the lithologic units.

Although Malott's work was based on a thorough knowledge of the landscape and topographic forms in Indiana, some of the boundary lines between units were rather arbitrarily drawn. The attempted quantitative characterization of these provinces in this study is in part a check to see if these boundaries were accurately placed.

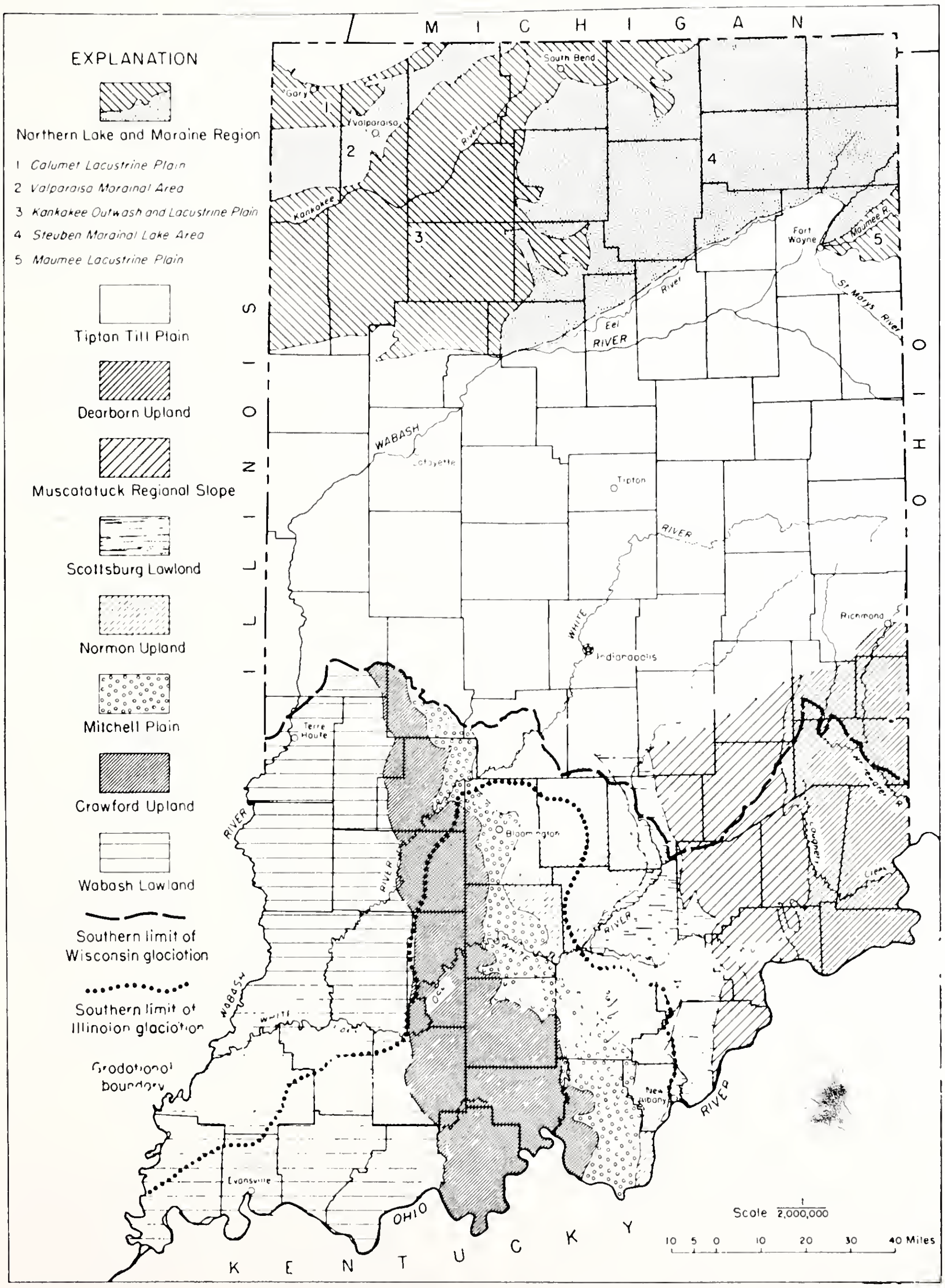


**FIGURE 1.** *Map of Indiana showing physiographic units (after Malott, 1922; and Wayne, 1953).*

Some attempts at quantitative topographic analysis have been reported. Chapman (1) constructed "statistical slope orientation (SSO)" diagrams by plotting and contouring slope direction and angle of inclination on an equal area projection. Elements of topography not easily discernible by other methods were revealed through SSO diagrams. A suggested application was the differentiation of physiographic units.

Lewis (3) used thirteen variables to measure surficial properties of landforms in Indiana, then applied principal components analysis to find the principal morphometric elements contributing to variance between stream basins. Using this approach allows numerical comparisons between regions and better complements process-oriented geomorphic studies.

Waldrip and Roberts (8), using data provided by the Conservation Needs Inventory, generated computerized slope maps of Indiana. These maps show that the physiographic units previously delimited by Malott are not uniform spatial units but show internal variation in landforms and topography.

## Method

U.S. Department of Agriculture soil survey maps (6) of Spencer, Perry, Crawford, Harrison, Floyd and Clark counties were used to derive slope data for the area studied. Six east-west transect lines at five-mile intervals were chosen (Fig. 2). These were analyzed by denoting the percentage of land in each of seven slope classes for every sampling unit along the transect. The slope classes are: A (0-2%), B (2-6%), C (6-12%), D (12-18%), E (18-25%), F (25-35%), G (>35%).

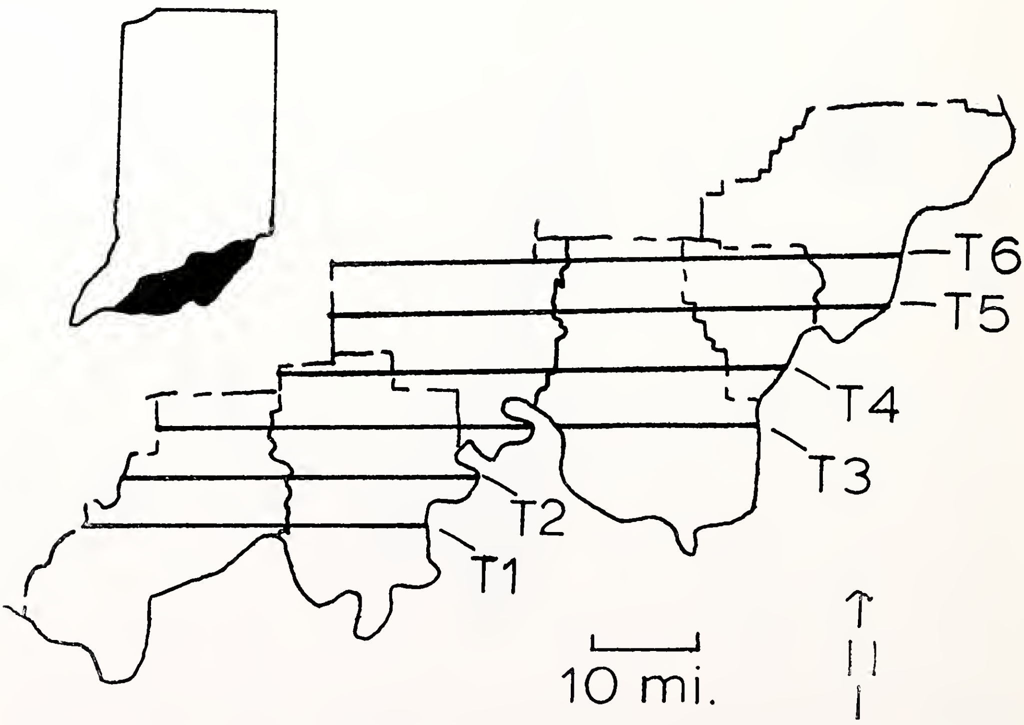


FIGURE 2. *Map showing location of transects. T1 . . . T6 refers to the transect numbers.*

The transects were of different lengths ranging from 33 to 50 miles, as dictated by the availability of published soil surveys. The size of the sampling unit also varied, being either a quarter or a third of a mile, depending on the scale of the soil map used.

The initial step in the data analysis was to calculate and plot along each transect average slope and percent of land with greater than C (12%) slope. The graphs were made with both raw values and running averages of five consecutive sampling units. Using running averages reduced much of the "noise" evident in the raw data and produced smoother, clearer graphs.

Knowing the location of established physiographic regions such as the Crawford Upland and Mitchell Plain, examination of these graphs showed a fairly good qualitative correlation with, for example, high slope values for uplands and lower values for lowlands, although there is a large amount of scatter. The graphs for percent greater than C slope (Fig. 3) show a more pronounced break between physiographic units than do those of average slope.

A more rigorous analysis using a statistic known as the distance function was then undertaken. The distance function computes the similarity of samples to a chosen representative sample (the center), using the equation

$$d = \sqrt{(A-A')^2 + \ldots + (G-G')^2}$$

where:

A . . . G = values (in percent) for each of the slope classes in the representative sample

A′ . . . G′ = slope values in the sample to be compared.

When the sample is identical to the center, d = 0. Larger values of d indicate greater differences between the sample and the center. As applied here, the points within a given physiographic region would be expected to have low d values when compared with the center of the region, while those points outside the unit should have higher d values.

Values A through G for a typical slope distribution of the Crawford Upland were computed as follows. A segment representative of the Crawford Upland was selected from transect 4 (Fig. 2) and the percentages in the slope classes for the 20 sampling units in this area were averaged to derive a center of (5, 6, 18, 37, 11, 23, 0). Comparison was made between this center and the slope distribution for each sampling unit along every transect using the distance function. The values of d plotted along each transect are shown in Figure 4.

## Results and Interpretation

Physiographic regions in southern Indiana, especially the Crawford Upland, are diverse with respect to topographic forms and slopes. The distance function shows this rather clearly (Fig. 4). Although the d values for the Crawford Upland are generally under some threshold (about 50 for the southern three transects and 40 for the northern three), there are wide variations. Outside the Crawford Upland are

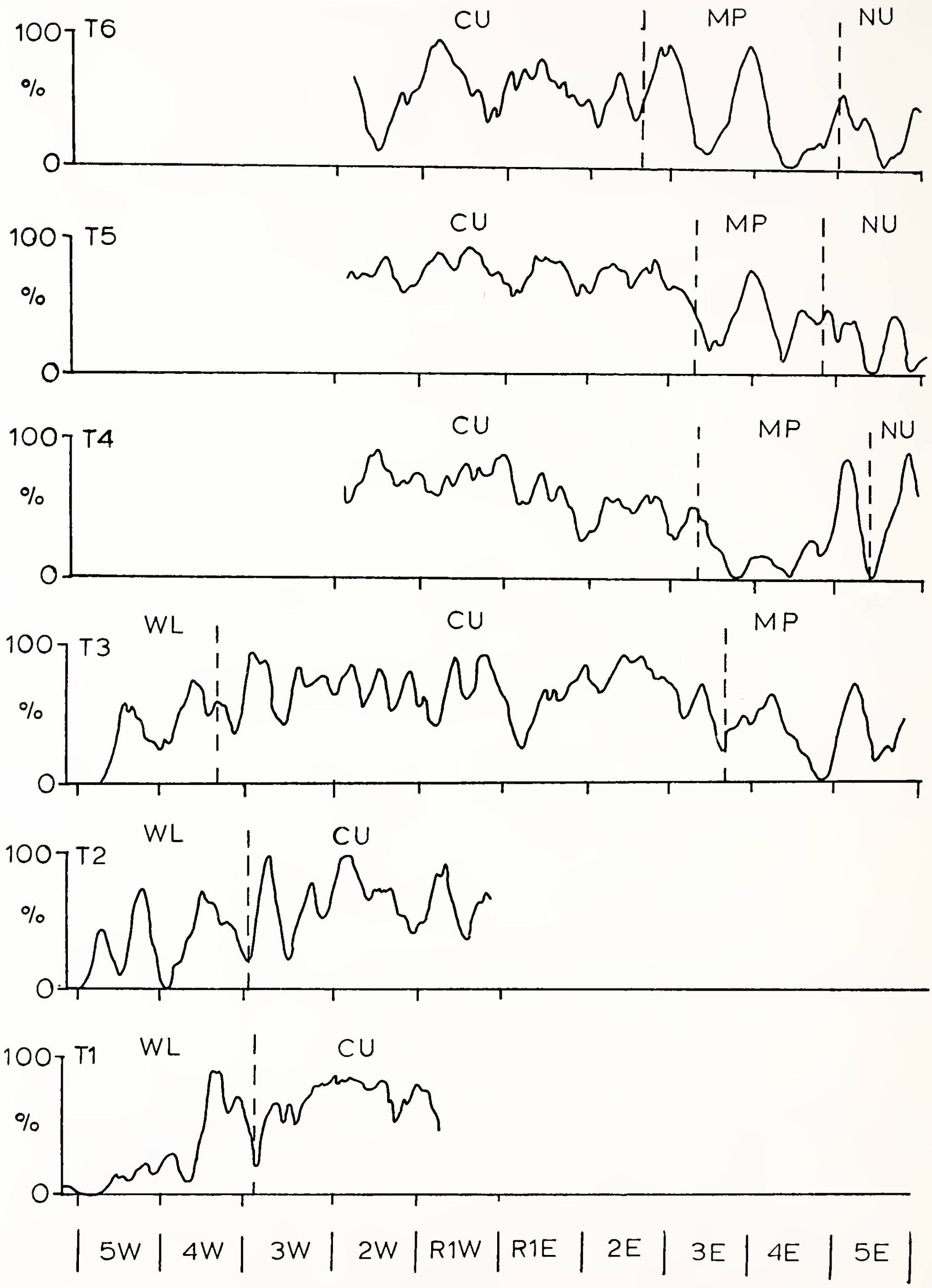


FIGURE 3. *Percent of land along each transect with slopes greater than C (12%). Dashed vertical lines mark physiographic unit boundaries. CU = Crawford Upland, WL = Wabash Lowland, MP = Mitchell Plain, NU = Norman Upland.*

some areas in which the slope distributions are sufficiently similar to the selected central area that the value of d is fairly low.

The Crawford Upland, covering an area of about 2900 square miles, is the most diverse southern Indiana physiographic unit in terms of different landforms and relief. The topography of this deeply dissected

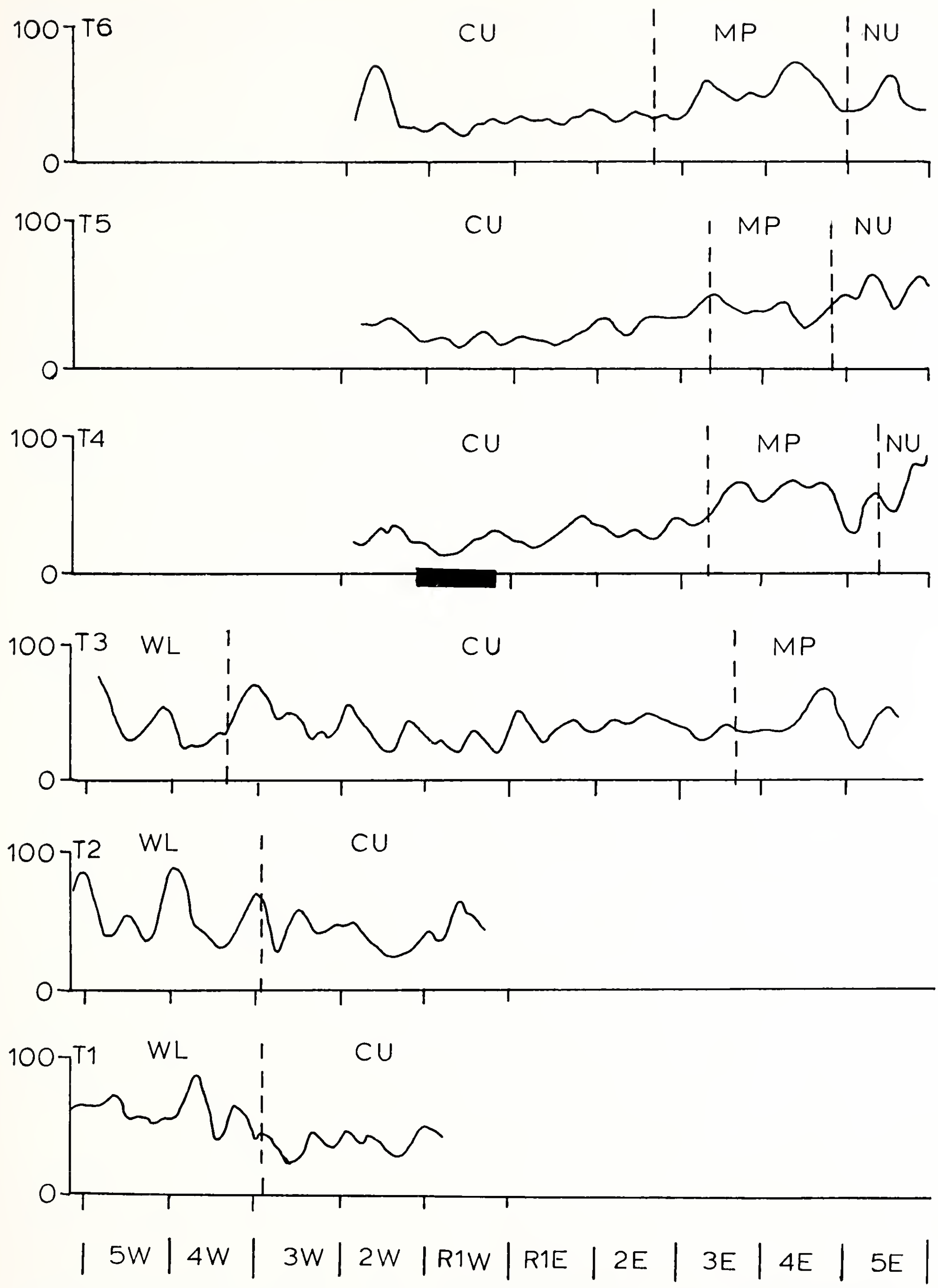


FIGURE 4. *Distance function (d) values along each transect. Heavy bar in transect 4 marks the central area used for comparison.*

upland is the result of differential erosion of the alternating sandstone, shale and limestone of the Chesterian Series (upper Mississippian) and the sandstone and shale of the Mansfield Formation (lower Pennsylvanian). (5)

The eastern boundary of the Crawford Upland is drawn along the base of the Chester Escarpment. The face of this cuesta scarp is very irregular. There are many outliers of clastic rock on the Mitchell Plain, and karst valley reentrants from the Mitchell Plain extend into the upland. In general, though, the boundary is marked by a significant change in topographic form and a great increase in altitude and relief. (5) On its western edge, the Crawford Upland grades transitionally into the Wabash Lowland. The relief is decreased and the valleys are more deeply aggraded. Malott drew the boundary line somewhat arbitrarily along this belt. (4)

The behavior of the distance values (Fig. 4) around the Crawford Upland boundaries is inconsistent, reflecting the nature of the established boundaries as discussed above. For two of the northern transects (4 and 6) there is a well defined break at the eastern edge of the Crawford Upland, but for transects 3 and 5 no such clear break is seen. The western edge, which is seen only on transects 1, 2, and 3, nowhere shows a definite break in d values. This is somewhat surprising in the case of transect 1 because a sharp drop in the percentage of slopes greater than C was evident a short distance to the west of the established boundary. A sharp rise in d was expected to correspond with this.

In order to relate the results of this analysis more directly to the land itself, USGS topographic maps (7) of the transect areas were examined. One transect showing a clear break in distance values at a boundary and one with an indistinct break were chosen for further study.

The distance function graph (Fig. 4) of transect 4 shows the eastern boundary of the Crawford Upland as a distinct break from lower to higher distance values. The area around this boundary in the Corydon West and De Pauw Quadrangles (Fig. 5) was examined.

In the western part of the map around the transect line, the topography consists of steep ridges and narrow valleys, with a few intermittent streams. East of there, the topography changes to ridges with gentler slopes, and farther east the land is much less steep and contains many depressions, which are sinkholes, and ponds, all of which are indicative of the Mitchell Plain. In this case, the transition from Crawford Upland to Mitchell Plain is sharp, with topography significantly changing within the distance of one to two miles.

In contrast, the western boundary of the Crawford Upland at transect 1 is gradational. Malott placed this boundary at the Anderson River, but the percent greater than C slopes data (Fig. 3) from this study show a clear break four miles west of the river. The distance function (Fig. 4), however, did not confirm this, instead showing two peaks before leveling off at a higher value in the Wabash Lowland.

The Fulda Quadrangle map (Fig. 6) covers the area where the transition from Crawford Upland to Wabash Lowland takes place in transect 1. There is some rugged terrain west of the Anderson River, with some flatter land directly adjacent to the river. West of Evanston, there is a more open landscape with flatter land. There are a few isolated steep "island" hills (which are characteristic of the Wabash Lowland) and ridges, but in general a noticeable change in topography

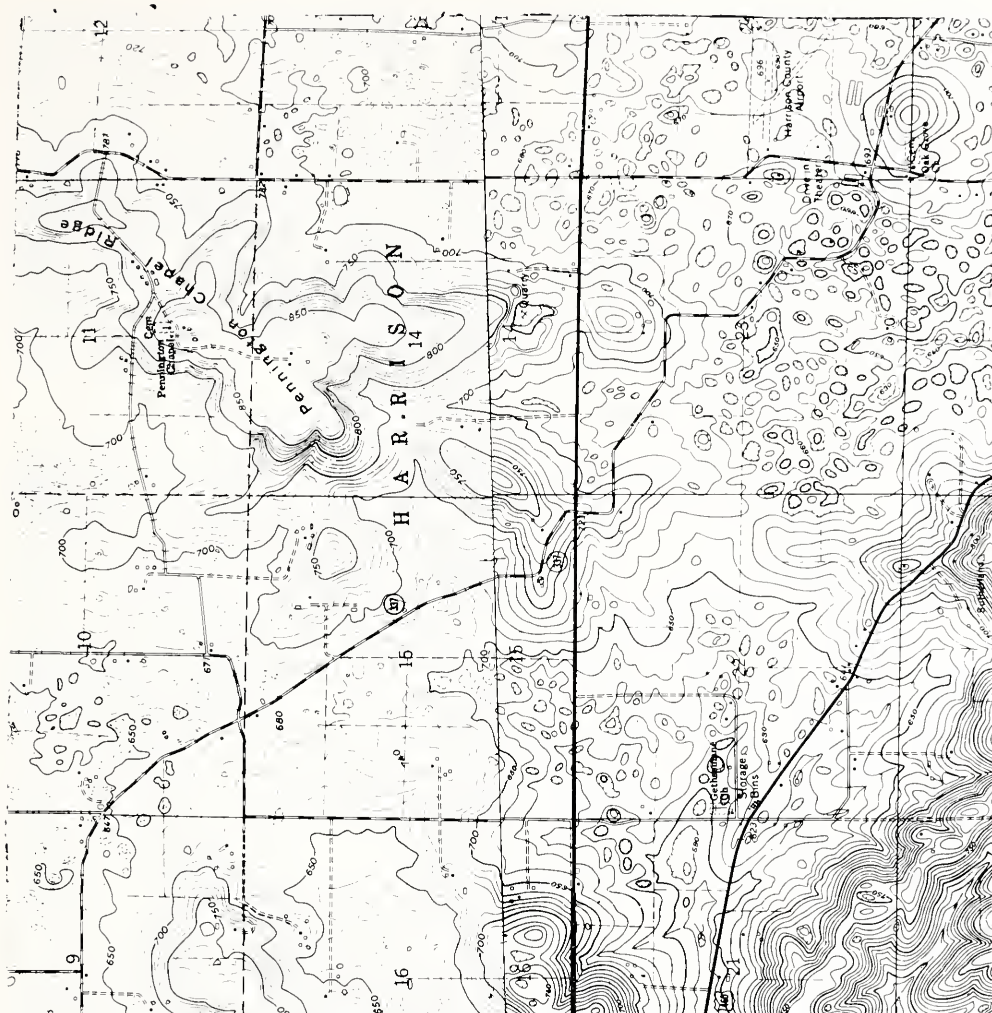


**Figure 5.** *Section of Corydon West and De Pauw Quadrangle maps (7-1/2 minute series) along transect 4. Transect location indicated by heavy black line running east-west.*

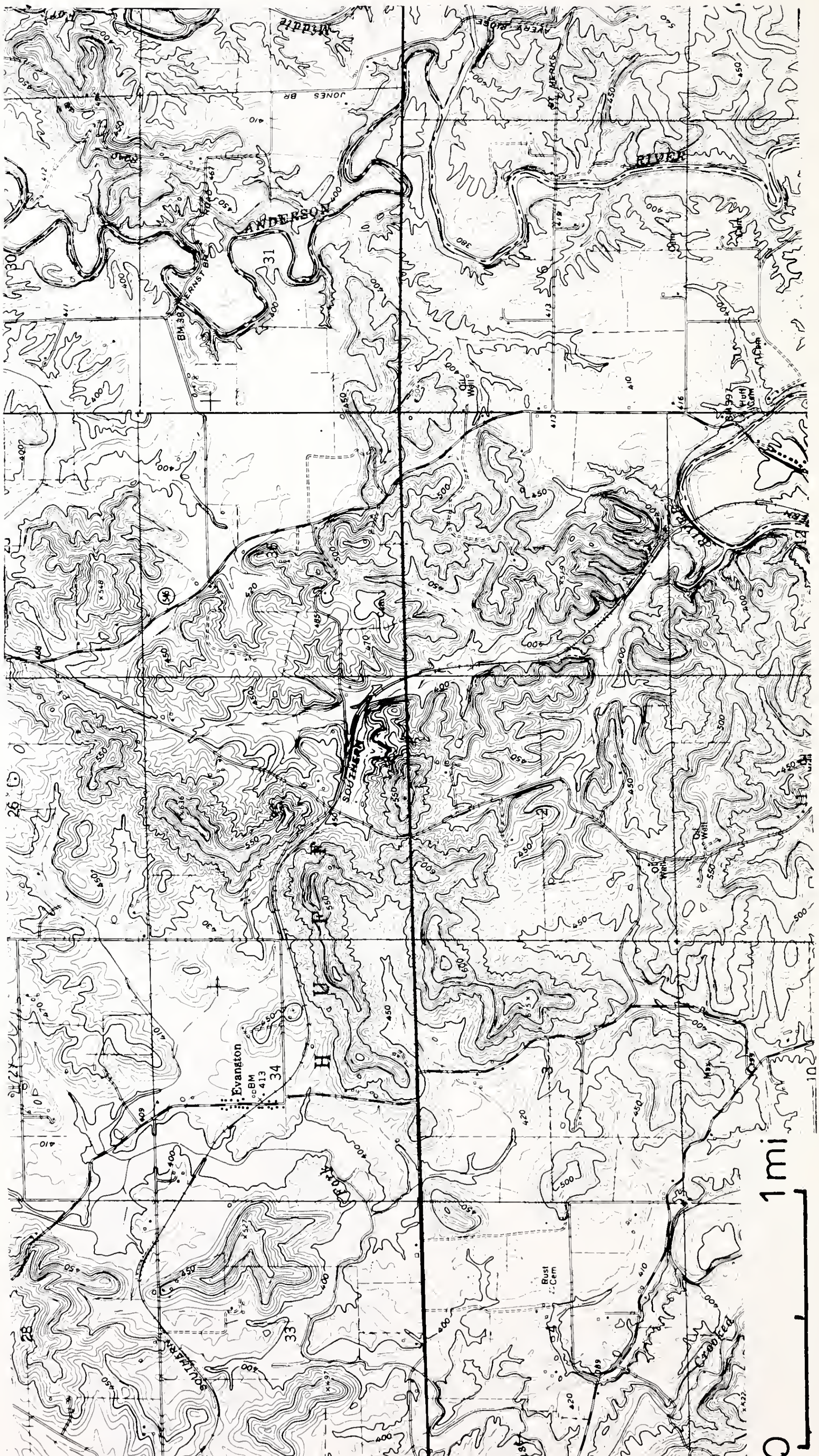


FIGURE 6. *Section of Fulda Quadrangle map (7-1/2 minute series) along Transect 1. Transect location indicated by heavy black line running east-west.*

is seen to the west. The clear break in slopes shown by the percent greater than C slope graphs is located where this change in topography begins. The transitional nature of the boundary indicated by the distance function is less easily explained by the topographic map.

In light of the irregularity of the eastern boundary and the transitional nature of the western boundary, it is clear why the distance function cannot everywhere make a clear differentiation between the Crawford Upland and the adjacent physiographic units, and why it is difficult to precisely place a border line. This suggests that no single parameter may be adequate to define the boundaries of the physiographic regions of southern Indiana.

## Conclusions

An evaluation of the analysis of slope distribution by the distance function as a means of defining physiographic units shows that although the distance function by itself canont be used to place a boundary between units, it is helpful in pinpointing areas that are problematic and may warrant further analysis by other methods.

Further study on this problem may result in the formulation of a quantitative method to characterize regional physiographic units such as those in southern Indiana. More comprehensive statistical methods like factor analysis or cluster analysis may prove to be more effective in achieving this end. The development of such a quantitative method is important so that the delimitation of regional physiographic units is rigorous and not subjective or arbitrary.

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