GRAPHIC ANALYSIS OF DRIFT TOPOGRAPHIES*

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ABSTRACT. A useful criterion for differentiation of glacial drifts of different ages is a comparison of their topographies. In general, analyses of drift topographies have been qualitative. A quantitative method of analysis which can be presented in simple graphic form is proposed. Time relationships of the drifts are determinable by interpretation of the frequency curves of drift topographies. Relationships of the Wisconsin drifts of northwestern Iowa are demonstrated by application of a graphic method.

INTRODUCTION

T. C. CHAMBERLIN (1878) emphasized the significance of differences in topographic expression as a means of differentiating glacial drifts. Since this pioneer work, topographic form has been utilized as a criterion of differentiation. However, analyses of drift topographies have been mainly qualitative. Lengthy, detailed descriptions have been employed to demonstrate existing differences. As a result, surfaces of considerable extent were interpreted on the basis of generalizations.

Topographic maps have been used to demonstrate differences of drift topographies. Alden and Leighton (1917, pp. 60-77) used portions of U. S. Geological Survey topographic maps to illustrate differences between Iowan and Kansan drift regions of northeastern and eastern Iowa. An adequate picture of a very small part of the drift regions is thus available. The major portions of the regions where topographic surveys had not been made were, of necessity, described in the accompanying general discussion.

Carmen (1931, pp. 40-48, 103-105) encountered difficulty in describing the topographies of the drifts in northwestern Iowa that he delineated as Iowan and Kansan. Restudy of these drift regions (here reclassified as Tazewell and Iowan) demonstrated to the present writer that they cannot be contrasted qualitatively. The regions contain the same topographic units. Comparison on a descriptive basis shows only that the drift topographies are similar. However, if a quantitative method of analysis is used, differences are noted.

In recent years aerial photographs have been used exten-

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sively in glacial studies. Interpretations based upon use of these field aids have also been mainly qualitative.

A method that reduces expressions of drift topographies to a concise form has not been presented, to the writer’s knowledge, in the literature. The following method has been found useful.

GRAPHIC METHOD OF ANALYSIS

In regions where topographic maps are lacking, analysis of slopes and relief can be made by a study of highway profiles. Profiles of primary roads are available in many states at the offices of highway commissions or offices of district resident engineers. Most glacial drift surfaces are traversed by networks of these primary roads.

The factors (1) slope and (2) relief are determined directly from the highway profile. In the generalized profile (fig. 1) slope in percent (s) is computed:

\[ s = \frac{y}{x} \times 100 \]

y is the difference in elevations between two adjacent high and low points in an increment of the traverse (X), and x the horizontal distance between those points. For example, slope of the portion of the profile ab is determined:

\[ s = \frac{y_5 - y_2}{x_1 - x_0} \times 100 \]

Similar computations are made for the portions of the profile bc, cd, etc. Relief is determined:

\[ r = y_m - y_n \]

\( y_m \) and \( y_n \) are the elevations of adjacent high and low points in an increment on the profile. For example, relief on the part of the profile ab is computed:

\[ r = y_5 - y_2 \]

Similar computations are made for the parts of the profile bc, cd, etc.

Slopes and relief of the highway profile are analyzed statistically by determining the values of these factors along the line of traverse (X). Brackets of quantitative values may be established. Slopes may be grouped conveniently into values which vary from 0-3, 3-6, 6-16, or 16-40 percent; relief ranges may
also be established, such as 20-40, 40-60, 60-80 feet, etc. Units are thus established which can be utilized for statistical purposes.

Analysis of frequencies of slope and relief units is possible if computation of slope and relief is made within equal increments of the total distance of the traverse (X). In figure 1:

\[ x_1 - x_0 = x_2 - x_1 = x_3 - x_2 \ldots \]

and

\[(x_1 - x_0) + (x_2 - x_1) + (x_3 - x_2) \ldots = X\]

For example, a traverse (X) consists of 100 increments. Slopes of 0-3 percent exist in 36 of the increments, slopes of 3-6 percent in 42 of the increments, slopes of 6-16 percent in 19 of the increments, and slopes of 16-40 percent in 3 of the increments. Frequencies in percent of the slope ranges are:

<table>
<thead>
<tr>
<th>Slope</th>
<th>Frequency-percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3</td>
<td>36</td>
</tr>
<tr>
<td>3-6</td>
<td>42</td>
</tr>
<tr>
<td>6-16</td>
<td>19</td>
</tr>
<tr>
<td>16-40</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

Several traverses may be analyzed and the average frequencies of each slope range determined. Results of the computation may be represented graphically in bar graphs or frequency curves. Values obtained by interpretation of a net of primary roads in a region covered with glacial drift can thus be compared with values obtained from a study of profiles of another region. Comparison of drift topographies is reduced to a comparison of mathematical curves.

![Figure 1. Generalized Highway Profile](image-url)
Accuracy of the graphical representation of drift topographies increases with the number of profiles analyzed. In northwestern Iowa, five east-west primary roads traverse the Tazewell and Iowan drift regions. Two north-south roads are located in each of the Tazewell and Iowan regions. Distances of fifteen to twenty miles separate the highways. The writer believes that this number of profiles should represent with a reasonable degree of accuracy the topographies of these drift regions.

Use of highway profiles for analytical purposes requires (1) a field check of the geographic location of the traverse to determine whether the true topography of the region is expressed by the profile, and (2) corrections for cuts and fills made in the course of highway construction. Evaluation of these factors is necessary for an accurate analysis. For example, in many places in the Kansas drift region of southwestern Iowa highways are emplaced along narrow topographic divides where gentle slopes exist. Profiles normal to the divides show the steeper slopes that are characteristic of the region. In this case the profile of the primary road does not express the true topography. Cuts and fills reduce the slopes of a drift surface. The highway profile must be converted to the true topographic profile by the addition of the depths of cuts and heights of fills to the convex sides of the swells and sags respectively of the highway profile. Field study is necessary to check the corrected profile. Corrected profiles should be used in the statistical analysis of drift topographies.

An alternative approach to a quantitative study of a drift surface may be made by using aerial photographs upon which altitudes taken during altimeter traverses have been plotted. Profiles are readily constructed and the above method of analysis employed.

A shortcoming of this quantitative method is that glacial constructional forms (end moraines, drumlins, etc.) must be incorporated in the profile analysis. Erosional and constructional slopes may fall within the same range and be grouped together. It is possible that an end moraine unmodified by postglacial erosion may be represented by a frequency curve which is the same as or very similar to the curve of a dissected ground moraine of an older drift. Therefore the graphic method is applicable only to comparisons of con-
structional topographies or erosional topographies if entire drift regions are analyzed. Modified and unmodified drift surfaces may be contrasted if the analyses are restricted to the same types of topography, for example, ground moraines.

An evaluation of the bedrock or other preglacial surfaces is necessary in order to determine their influence upon the present drift surfaces. For example, the frequency curve of the topography of a thin older drift mantling a relatively flat bedrock surface may be quite similar to the curve of a young unmodified till plain where bedrock does not influence the surface expression of the drift. Field study, however, would show these relationships. In the following section a graphic method of analysis is applied to the drifts of northwestern Iowa. The thicknesses of these drifts are believed to be of such a magnitude that the existing surfaces of the drifts are not influenced by the character of their preglacial surfaces.

**APPLICATION OF METHOD**

Four Wisconsin drifts have been identified and mapped recently by the writer in northwestern Iowa; the drifts are recognized as the Iowan, Tazewell, Cary, and Mankato. Field study showed that the Iowan and Tazewell drifts are well drained and have had integrated drainage systems developed on their surfaces. Undrained depressions are lacking. These two drifts are very similar topographically. Local areas of level, undulating, rolling, and dissected ground moraine occur, and because of this relationship the regions cannot be differentiated on a qualitative basis. However, the frequency of occurrence of these topographic units differs (fig. 2). The regions may be differentiated on a quantitative basis.

The Iowan and Tazewell drifts are bordered to the south in western-central Iowa by the Kansan drift. This older drift differs distinctly from the younger drifts and is maturely dissected and characterized by steep slopes. The difference is particularly evident when the frequency curves are compared.

The Cary and Mankato drifts are very similar topographically but differ decidedly from the Iowan and Tazewell drifts in this regard. The two later drifts are margined by vigorous end moraines with well-aligned trends. End moraines also exist at variable distances behind the marginal moraines. Intermorainic till plains of low relief constitute appreciable
portions of the drift regions. Field study showed that both regions are very poorly drained in the end- and ground-morainal areas. Integrated drainage systems have not been established on these drift surfaces. Undrained depressions are abundant. Similarity of the ground-morainal topographies of the Cary and Mankato drift regions is demonstrated by the Cary and Mankato curves (fig. 2). Evidence that the

![Frequency Curves of Ground-Morainal Topographies](image-url)
Iowan and Tazewell topographies differ from the Cary and Mankato is shown by the slope curves of the four drifts.

The frequency curves in figure 2 represent the topographies of the ground moraines of the various drifts. No end moraines exist in the Kansan or Iowan regions. A subdued, patchy end moraine that exists at or near the margin of the Tazewell drift is excluded from the analysis. The end moraine constitutes only one to two percent of the Tazewell drift region. The frequency curves of the Kansan, Iowan, and Tazewell therefore essentially represent the topographies of these drift regions. In figure 3 the topographies of the whole of the Cary and Mankato regions are represented. End and ground moraines are included in the analyses. Similarity of these drift topographies is evident.

Computation of the frequency curves of the slope topographies of the Kansan and Wisconsin drifts is based upon a slope study by the soil survey personnel of the Iowa Agricultural Experiment Station (1949).

RELATIONSHIP OF TOPOGRAPHIC EXPRESSION AND TIME

Frequency curves of the Kansan, Iowan, Tazewell, Cary, and Mankato topographies show the time relationships of these drifts. Peaks of the frequency curves shift from low-slope to high-slope values as the age of the drift increases. Peaks of the Mankato and Cary curves fall within the 0-3 percent range whereas those of the Tazewell and Iowan curves shift to steeper slope values, 3-6 percent. The Kansan modal is in the steepest slope range, 16-40 percent.

Pertinent to study of the Wisconsin drifts is the relationship which exists between the Mankato, Cary, Tazewell, and Iowan curves (fig. 2). Similarity of the Mankato and Cary curves (also fig. 3) indicates that these two drifts are closely related in time. The same relationship exists between the Tazewell and Iowan curves. Comparison of the curves of the Mankato and Cary to the Tazewell and Iowan indicates that the major time break in the Wisconsin sequence occurred during the Cary-Tazewell interval. Field study showed that integrated drainage systems have been established on the two older Wisconsin drifts but not on the two younger drifts. An interval of time of substantial duration was necessary for the establishment of drainage. Comparable time intervals between the Mankato and Cary
and the Tazewell and Iowan are precluded by the similarity of existing topographies as demonstrated by the frequency curves.

CONCLUSIONS

Quantitative analyses of drift topographies can be made by the simple method detailed in the foregoing statement. Analyses can be presented in simple graphic form. Comparison of drift topographies is reduced to a comparison of mathematical curves. Knowledge of the time relationships of the drifts is gained by interpretation of these curves.
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