Proceedings of the Iowa Academy of Science

Volume 71 | Annual Issue Article 48

1964

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Abstract. A morphometric study was made of the adjoining drainage basins of east-flowing Old Man Creek and Clear Creek in Johnson and Iowa counties, Iowa. In terms of the parameters measured, these basins are essentially similar. They agree with "laws" for drainage basins proposed by Horton and are therefore "normal" rather than "misfit". Part of the Clear Creek basin was invaded by Iowan ice and this probably accounts for some abnormal data. Distinct longitudinal asymetry and obviously steeper south valley walls are probably best explained by the differences in loess thickness on valley sides.

INTRODUCTION

The valleys of Clear Creek and Old Man Creek, right-bank tributaries of the Iowa River, extend upstream in a westward direction from the vicinity of Iowa City. The local geology and geomorphology is well presented in Calvin (1897), Stookey (1909), Leighton (1914) and Dow (1959). Principal highways follow and cross these basins (Fig. 1). Observing the broad flat floors of these valleys, which lie between fairly steep walls, the authors hypothesized, in general terms, that these streams were "misfits" within their valleys. Did these small shallow streams erode the valleys that they now occupy? Are the valleys normal for the present conditions of discharge?

This study is an attempt to describe these two stream valleys using the techniques of quantitative morphometric analysis, supplemented by local geologic observations. The results will be evaluated in terms of the morphometric "laws" of "normal" streams as proposed by Horton (1945) and compared with the local geology.

QUANTITATIVE MORPHOMETRIC ANALYSIS

Until the middle of the 20th Century the description and analysis of landforms, in the main, was purely qualitative. In a classical paper by Horton (1945) the geomorphologist was given many of the necessary tools by which he could quantify his observations. Strahler (1958, summary publication) and his students have supplemented and modified many of Horton's physiographic parameters.

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Proceedings of the Iowa Academy of Science, Vol. 71 [1964], No. 1, Art. 48

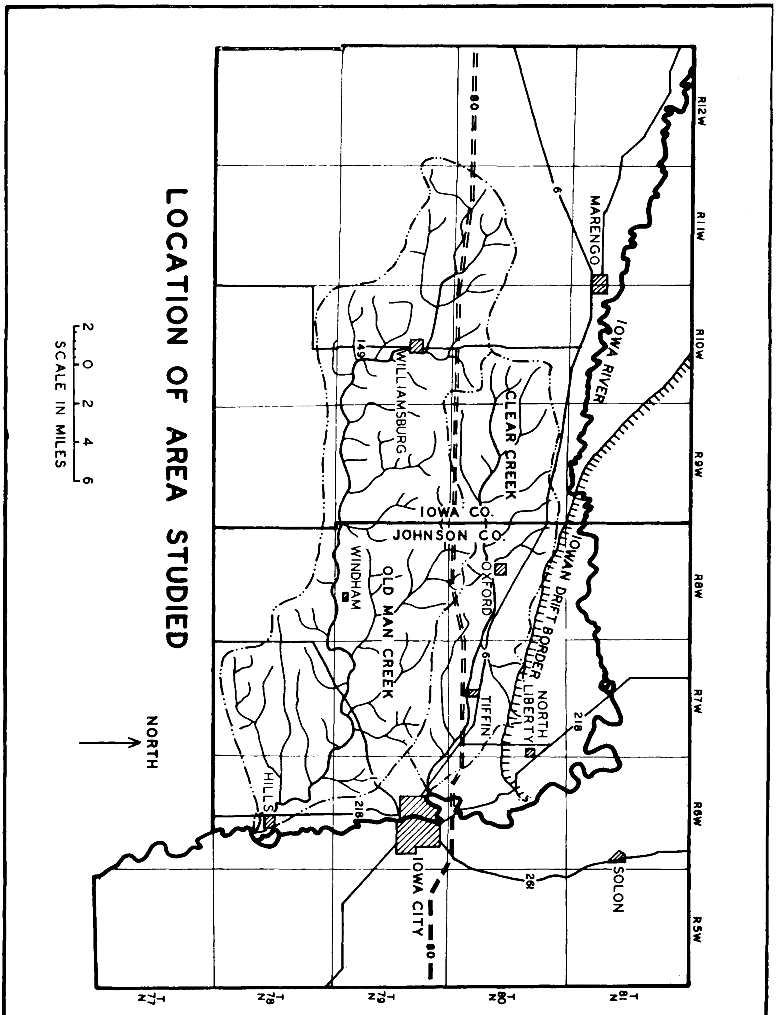

Figure 1. General location map of Clear Creek and Old Man Creek in Iowa and Johnson Counties, Iowa.

Construction of Base Map

Large scale topographic maps (scale of 1/24,000 or larger) are needed for quantitative morphometric analysis. Morisawa (1959, p. 5-6) and others have found that topographic maps of scale 1/62,500 are not reliable for measuring drainage basin characteristics, except for area, unless the maps are corrected by field observations. In the area under study the following topographic map coverage is available: Davenport 1962 ed. and Des Moines 1957 ed., CI 50 ft., scale 1/250,000; Fairfax 1903 ed., CI

20 ft., scale 1/125,000; and Iowa City, 1938 ed., Oxford, 1894 ed., Amana, 1899 ed., and Cedar Rapids 1891 ed., CI 20 ft., scale 1/62,500. Three of the four 1/62,500 quadrangles are simply enlargements of three quadrants of the Fairfax sheet.

Because of the lack of proper scale topographic maps the stream patterns of the two basins were traced from the Agricultural Stabilization and Conservation Service aerial photographs of scale 1/15,625 obtained from the Johnson and Iowa county offices of the U. S. Soil Conservation Service. An overlay was made on a frosted acetate base by using a stereoscope to properly locate stream channels and drainage divides. The original overlay, approximately 6 feet by 12 feet, was difficult to work with because of its size, and was photographically reduced to a scale of 1/31,250. This original map compilation is the most detailed planimetric map available for this area (Fig. 2).

Morphometric Procedures

Melton (1957, p. 2) has subdivided morphometric terrain parameters into two main categories: "basic properties", consisting of physical attributes measured or counted directly from topographic maps or field observations and "derived properties", which include those factors which must be obtained by computational methods.

The method of stream ordering is that of Horton (1945) as revised by Strahler (1952, p. 120). Length measurements were made with a Hamilton map measurer and areas determined with a compensating polar planimeter. A special measurement for areal asymmetry of the basins was developed for this study. Right intra-basin area is defined as that portion of the drainage basin located to the right, facing downstream, of the major stream draining the basin; left intra-basin area is the portion to the left. The maximum slopes of the valley sides were measured in the field in degrees with a Brunton compass.

Morphological Comparison of Old Man Creek with Clear Creek

In view of Strahler's (1958, p. 291) statement that landforms developed by similar geological processes and on similar materials are generally recognized to possess a considerable degree of similarity, a comparison of the morphologic measurements of Old Man Creek with those of Clear Creek should reveal any basic difference between the two basins. Each basin was systematically analyzed according to the preceding terrain factors. The data were compiled and are presented in Tables 1 and 2.

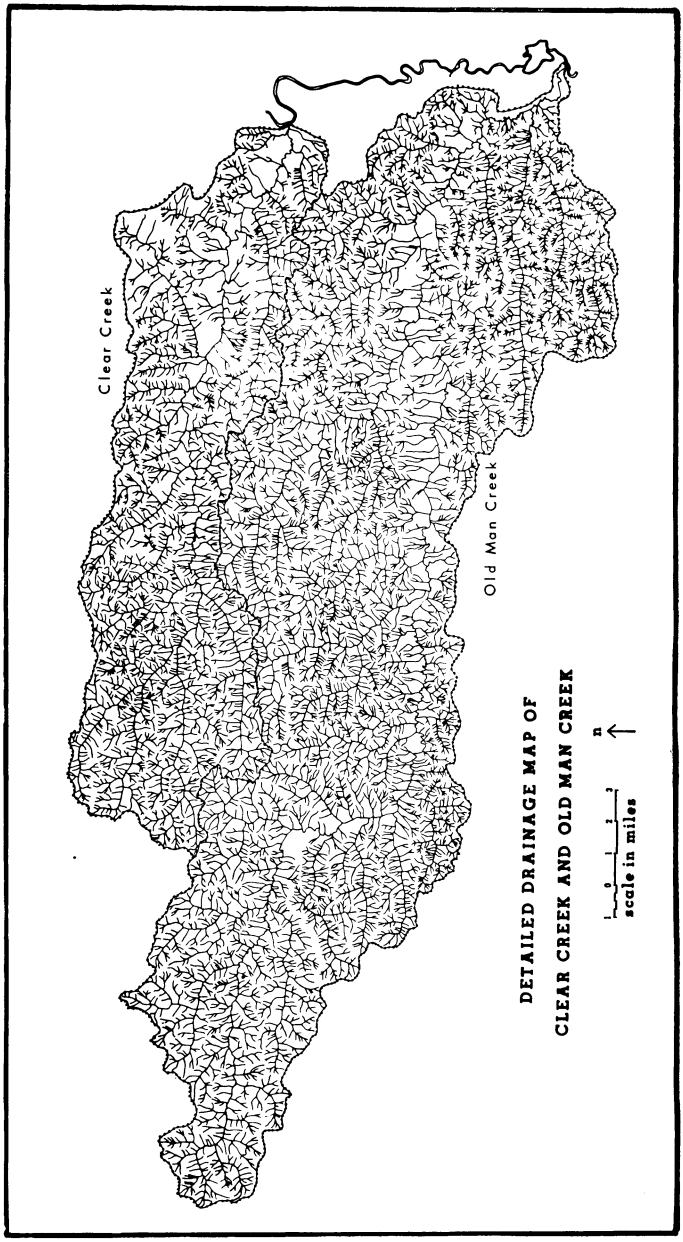

Figure 2. **Detailed drainage map of Clear Creek and Old Man Creek.**

On completion of the ordering procedure, it was found that Clear Creek was a sixth order basin while Old Man Creek was a seventh order basin.

Table 1. Observed Physiographic Parameters Basic Properties.

Property	Symbol	Units	Clear Creek	Old Man Creek
Basin order- Stream order	u	enumerative	6	7
Number of streams of each order	Nu	enumerative		
1st			1885	5156
2nd			461	1143
3rd			98	249
4th			18	48
5th			4	12
6th			1	2
7th				1
Total number of all stream segments	ENu	enumerative	2467	6611
Mean stream length of each order	Lu	miles		
1st			0.231	0.214
2nd			0.284	0.279
3rd			0.595	0.552
4th			2.052	1.736
5th			2.157	3.442
6th				14.855
Total stream length of all orders	EL	miles	691.260	1738.750
Mean basin area of each order	$\overline{Au}$	square miles		
1st			0.030	0.029
2nd			0.135	0.127
3rd			0.604	0.530
4th			3.617	3.120
5th			10.925	10.310
6th				79.510
Total basin area of main basin	Au	square miles	106.20	251.42
Right intra-basin area	Ar	square miles	40.16	102.31
Left intra-basin area	Al	square miles	66.04	149.11
Mean basin length	$\overline{Lb}$	miles		
4th			3.110	2.700
5th			6.280	5.363
6th			23.750*	19.500
7th				38.500*
Mean basin width	$\overline{Wb}$	miles		
4th			1.460	1.552
5th			2.350	2.700
6th			6.500*	6.500
7th				10.750*
Mean maximum angle left valley side slopes	$\overline{\theta l}$	degrees	7.85	5.80
Mean maximum angle right valley side slopes	$\overline{\theta r}$	degrees	10.46	8.83

* True value

It can be seen from Table 1 that Old Man Creek has from two to three times as many streams of each order, as that of Clear Creek. This dissimilarity in stream numbers is not indicative of a true difference in the drainage composition. Since Old Man

Table 2. Observed Physiographic Parameters Derived Properties.

Property	How derived	Units	Clear Creek	Old Man Creek
Drainage density	Dd=EL/Au	miles/square mile	6.51	6.91
Stream Frequency	F=ENu/Au	number/square mile	23.23	26.29
Bifurcation ration	R_b=Nu/Nu+1	number/number		
1st			4.09	4.51
2nd			4.70	4.59
3rd			5.44	5.19
4th			4.50	4.00
5th			4.00	6.00
6th				2.00
7th				
Weighted mean bifurcation ration	(see Schumm, 1954, p. 12)		4.26	4.55
Bas length-width ration	Rlw=Lb/Wb	miles/miles		
4th			2.06	1.91
5th			2.72	2.07
6th			3.65*	2.86
7th				3.58*
Symmetry ratio	Rs=Al/Ar	sq. miles/sq. miles	1.64	1.46
Mean symmetry index	Is=θl/θr	degrees/degrees	0.88	0.78

* true value

Creek is a higher order basin than Clear Creek, it would be expected to have a greater number of streams per order.

In computing the mean basin area and stream length, the entire population of all second and higher order basins were measured. The means of first order basin areas and stream lengths were derived from a 10 percent random sample. The number of first-order basins and streams in each of the two major basins was known; hence approximate values of total basin area and stream length could be calculated.

In comparing the mean basin areas of the respective orders of the two major basins, it can be seen that those of Clear Creek tend to be consistently slightly greater than those of Old Man Creek. Likewise, except for the fifth order, the mean stream lengths of Clear Creek are slightly greater than those of Old Man Creek indicating that the drainage of Old Man Creek is somewhat more integrated than that of Clear Creek.

The mean basin lengths of Clear Creek tend to be greater than those of Old Man Creek. On the other hand, the mean basin widths of Old Man Creek, except for the sixth order, are slightly greater than those of Clear Creek. This indicates that the stream basins comprising Clear Creek drainage tend to be slightly longer and narrower than those of Old Man Creek.

The right and left intra-basin areas of the major drainage basins were measured and recorded. It can be seen that in both basins the greater portion of the drainage area is concentrated to the north of the major stream.

In determining the mean maximum slope angle of north- and south-facing valley slopes, a total of 112 measurements, half on the north and half on the south, were made in both basins. Of this total, 60 were taken in the valley of Old Man Creek and 52 in the valley of Clear Creek. The data clearly indicates that north-facing valley slopes tend to be steeper than south-facing slopes.

Clear Creek has a lower drainage density (6.51) than Old Man Creek (6.91), which supports the previous suggestion that the drainage network of Old Man Creek is more integrated. This is nothing more than a quantitative statement suggesting that Old Man Creek basin is better drained than the Clear Creek basin. The figures for stream frequency and the weighted mean bifurcation ratio confirm this. In considering the bifurcation ratios between the individual basin orders no consistent relationship can be observed. The ratio between first to second and fifth to sixth order basins in Old Man Creek is greater than the corresponding value for Clear Creek whereas the ratio between second and third and third to fourth order basins is less than Clear Creek.

The basin length to width ratio was computed in this study in order to determine the characteristic shapes of the drainage basins. Horton (1945, p. 365) suggests that where strong geologic controls are lacking, most drainage basins will assume an ovoid or pear-shaped form. Our basins definitely do not fit this description. As can be seen from the values in Table 2, the basins are subrectangular in form, with Clear Creek's basins being more elongated than Old Man Creek's basins. Usually the lower order basins approach a more circular shape than the higher order basins.

The symmetry ratio is introduced here in an attempt to quantitatively describe the asymmetry of the two basins. Both basins have the greater part of their drainage area to the north of the major stream. Figure 1 shows how the northern tributaries of Old Man Creek in some areas along the drainage divide reach within less than a mile of Clear Creek. The asymmetrical aspect of the two basins can be clearly seen by observing Figure 3 which was developed from data taken from the topographic maps. In this diagram the base of each triangle is proportional to the horizontal distance from the main stream to the drainage divide; the vertical leg of the triangle is proportional to the difference in elevation between the stream and the drainage divide. In both basins the areal symmetry tends to be *greatest near* the middle rather than at the mouths and the sources.

The mean symmetry index indicates that the valley walls to the right of the main stream in both basins have a steeper maximum slope angle than those to the left.

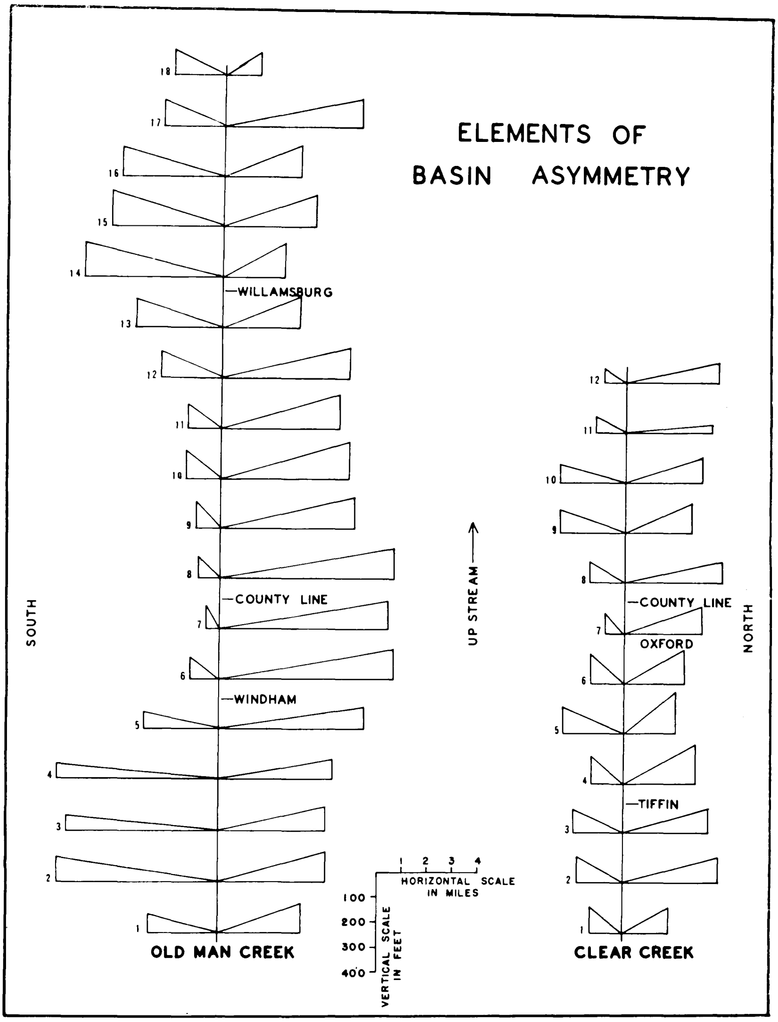

Figure 3. Generalized profiles perpendicular to valley showing basin asymmetry.

Comparison with Established Laws of Drainage Composition

Horton (1945, p. 286) from a study of physical characteristics of numerous drainage basins formulated certain laws of drainage composition relating numbers of streams, stream lengths, stream slopes, and basin areas respectively to order number. From a study of graphs of basin properties versus order number, Horton found that the relationship was best described by a geometric series. If a geometric series exists, a series of points lying on a straight line may be expected when the numerical values of the basin properties of each order are plotted on a logarithmic scale on the ordinate against order numbers on an arithmetric scale on the abscissa (Schumm 1954, p. 12). The number of streams, mean stream length, and mean basin area of each order basin of Clear Creek and Old Man Creek were plotted against their respective order numbers on semi-logarithmic coordinate paper to see if they fitted Horton's "laws".

The law of stream numbers as defined by Horton (1945, p. 291 states:

> "The numbers of streams of different orders in a given drainage basin tend closely to approximate an

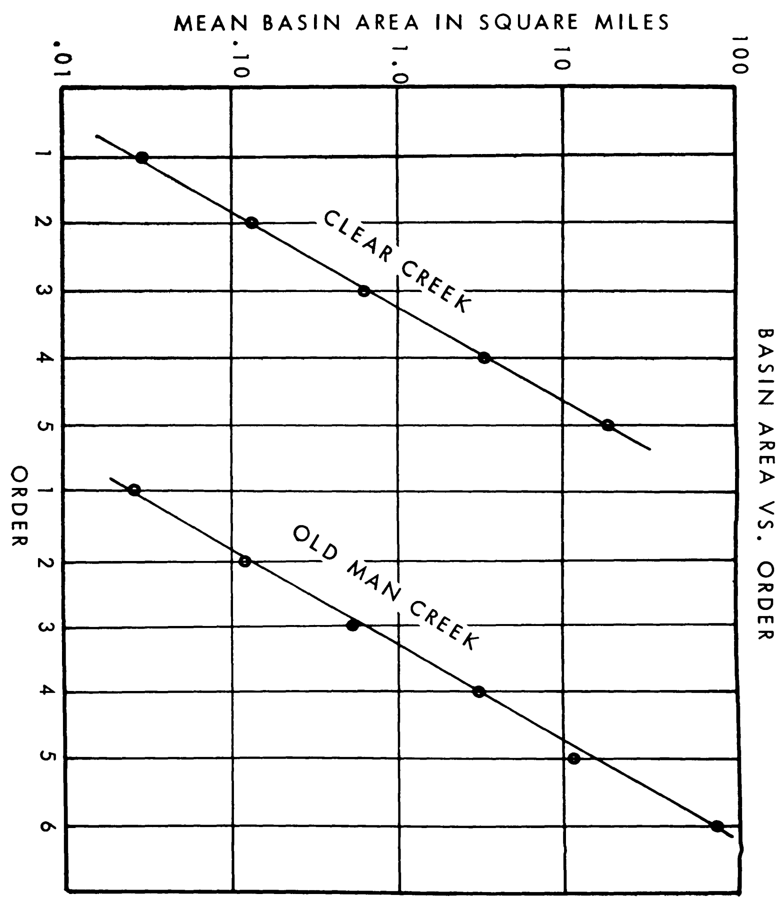

Figure 4. Relation of number of streams to stream order.

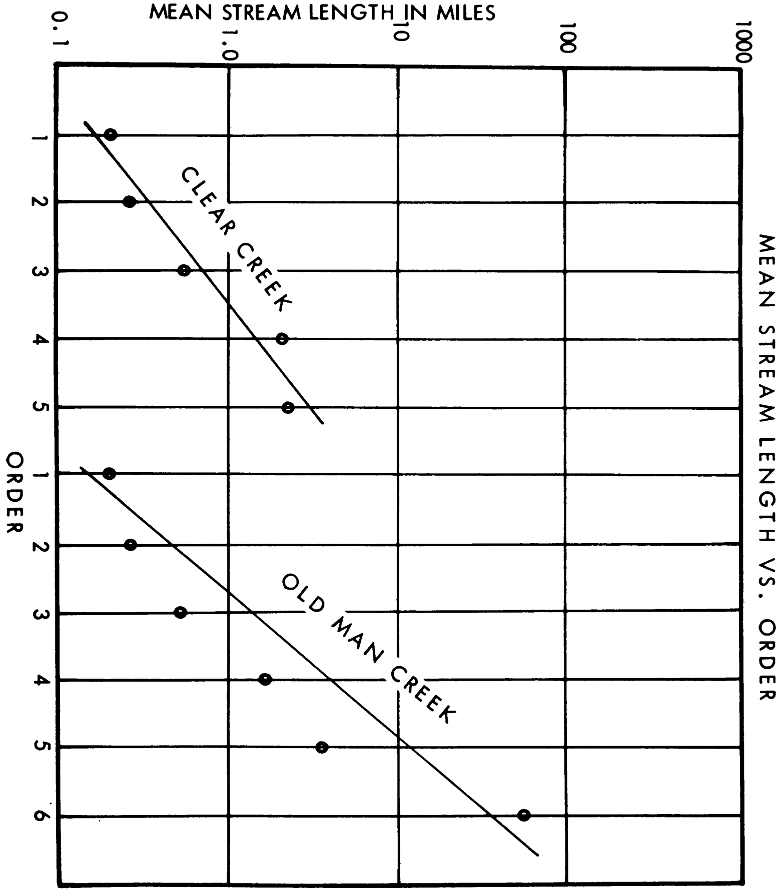

Figure 5. Relation of mean stream length to stream order.

inverse geometric series in which the first term is unity and the ratio is the bifurcation ratio."

Figure 4 shows number of streams of each order plotted against order number, with the lines of best fit drawn by inspection. Data from our basins conform very closely to the law of stream number.

The law of stream lengths is defined by Horton as:

"The average lengths of streams of each of the different orders in a drainage basin tend closely to approximate a direct geometric series in which the first term is the average length of streams of the first order."

The Clear Creek and Old Man Creek mean stream length data do not seem to fit a geometric series as closely as might be ex-

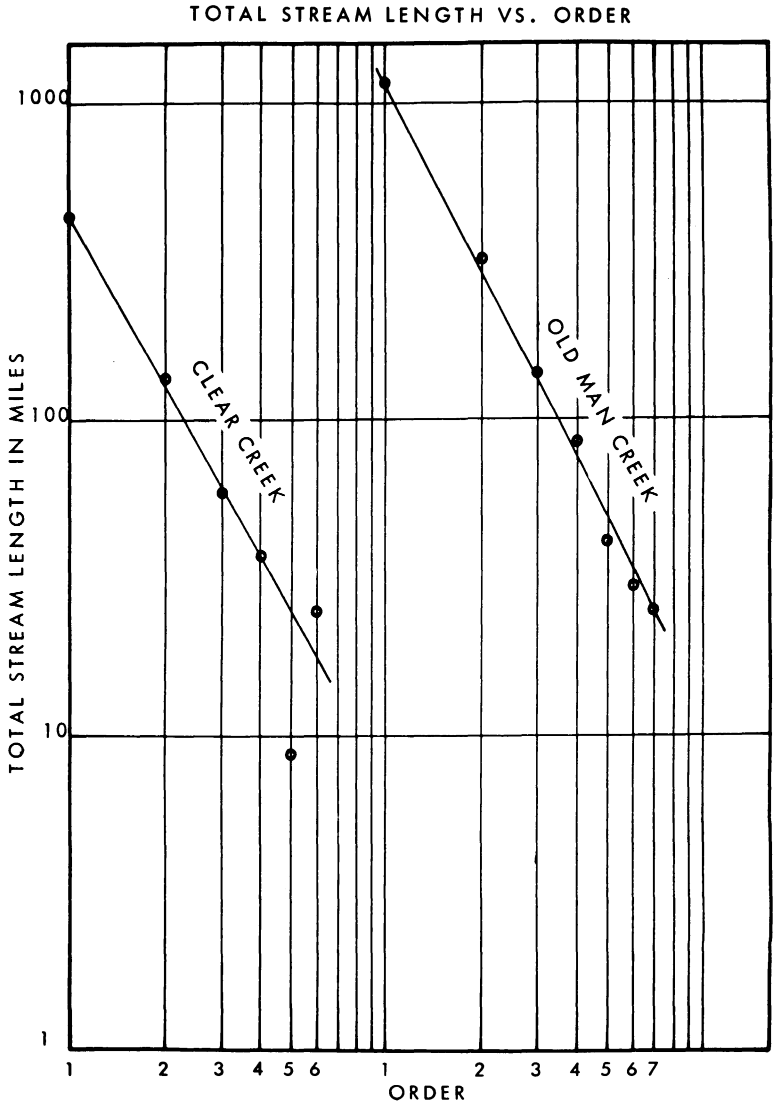

Figure 6. Relation of total stream length to stream order.

pected. As can be seen in Figure 5, the mean lengths of first and fourth order streams of Clear Creek are too great. Likewise the mean lengths of the first and sixth-order streams of Old Man Creek appear to be too great. Other investigators have found in using Horton's law of stream lengths similar discrepancies. It has been suggested that the departure from a true geometric series is due to Strahler's revision of Horton's method of ordering (Broscoe, 1959, p. 5). Strahler (1957, p. 915) has, therefore, suggested a revision of this law whereby the logarithms of total stream length of each order are plotted against the logarithms of order numbers. Thus a revised law of stream lengths may be stated:

> "The total lengths of streams of the different orders in a drainage basin tend closely to approximate an inverse logarithmic series in which the first term is the total length of streams of the highest order" (Chorley, 1957, p. 144-145).

As can be seen in Figure 6 Old Man Creek seems to conform very well to the revised law but in Clear Creek's basin the total length of fifth-order streams seems to be out of accord with the lower orders.

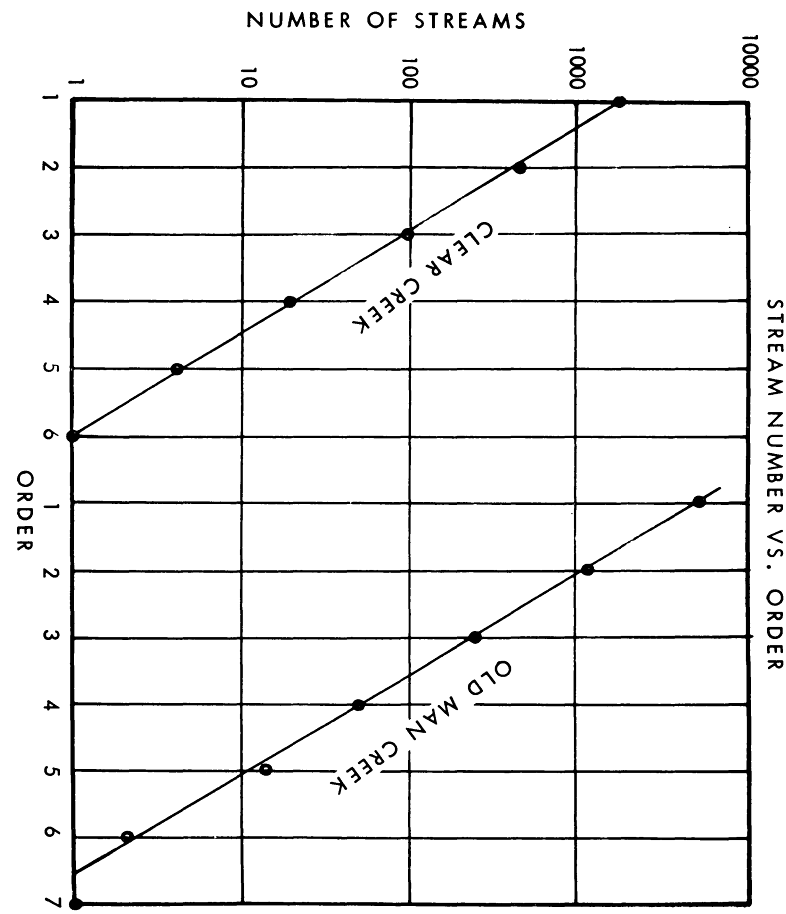

Figure 7. Relation drainage basin area to stream order.

The law of basin areas was implied by Horton (1945, p. 294) but was first explicitly defined by Schumm (1954, p. 14-15) as:

> "The mean drainage areas of streams of each order tend closely to approximate a direct geometric series in which the first term is the mean area of first order basins."

As can be seen from Figure 7 the mean basin area data of Clear Creek and Old Man Creek seem to conform very closely to the law of basin areas as stated by Schumm. The law of stream slopes could not be readily tested because of the lack of topographic maps.

Summary and Conclusions

Examination of our data shows that slight differences appear to exist between the morphological parameters of Clear Creek and Old Man Creek. The basin shapes and cross section symmetry are somewhat atypical, and Clear Creek does not conform closely to the law of total stream lengths.

In considering the differences in morphological parameters of these two basins no objective scale relating the magnitude of difference to the relative degree of correspondence between compared parameters in available. Therefore any evaluation in the degree of similarity or dissimilarity is subjective.

The smallest difference (Table 1), .001 square miles, between the first order mean basin areas while the greatest difference, 4.25 miles, is between the sixth order basin lengths. Certainly a difference of .001 square mile could be the result of operational error in making the measurements, whereas those approaching a greater magnitude probably reflect a true difference. The consistency of the differences should also be taken into consideration. It can be seen that the mean basin areas, mean stream lengths (except for fifth order), and mean basin lengths for each order basin of Clear Creek are consistently greater than those of the corresponding basins of Old Man Creek. It is, therefore, suggested that the magnitude and consistency in the differences between the observed parameters indicate that the drainage of Old Man Creek is slightly more integrated than that of Clear Creek. This is supported by the greater mean stream lengths (except for fifth order), mean basin area, and mean basin lengths of Clear Creek's basin and by the higher values of drainage density, stream frequency, and weighted mean bifurcation ratio of Old Man Creek's basin.

The difference in the drainage development of these two basins was suggested by Calvin (1897, p. 48-50) in the following statement concerning Clear Creek's drainage basin:

> "During the Iowan stage the northern part of this normally developed drainage area was invaded by the North Liberty lobe of Iowan ice; and marginal deposits of sand and loess were piled up inside the basin in such a way as to obliterate the regularly developed channels on the north side of the valley."

In regard to Old Man Creek's drainage he states: (See Figure 1 for location of Iowan drift border)

> "Its drainage area is normal. The natural course of development suffered no interference by the encroachment of Iowan ice, or accumulation within its area of marginal deposits of loess."

Data from this study seem to confirm Calvin's suggestion.

Although these drainage basins are abnormally long, this is not a unique characteristic of these two basins. McGee, as early as 1890, (p. 359) in writing about the physiography of northeast Iowa pointed this out.

> "The most striking characteristic of all these streams is their great length in proportion to volume and the striking characteristic of the basins is their length and slenderness."

Previous authors have attributed the elongation and parallelism of the streams in eastern Iowa to such mechanisms as the structural control of the bedrock (Whitney, 1858) and longitudinal ridging of the original drift surface (White, 1870; McGee, 1890). At present no single answer to this problem is readily available.

The asymmetry of stream basins and variation in left and right valley side walls (Fig. 3) have in the past been attributed to a variety of causes. Among the more popular are: lateral downdip shift of stream axis along weak strata, earth's rotation (coriolis force), recent regional tilting, and differences in amounts of insolation and weathering on differently oriented slopes.

From field observations and the comparison of contour maps of the bedrock surface (Beveridge, 1947, and Dow, 1959) to topographic maps of the area it is apparent that the bedrock has exerted little if any control on the development of the two basins. The suggestion that the streams are migrating down the dip of weaker beds can therefore not be accepted.

The effect of the coriolis force would be slight on east flowing streams.

The influence of the regional slope of the drift plain on the development of these stream basins has not been fully analyzed. The slope of the drift surface in this area is to the southeast. The two stream basins under study trend east-west or about 45° from the regional slope. No information is available to indicate whether the present southeast slope was the original slope or not. While the major rivers of eastern Iowa flow southeast, inspection of topographic maps of eastern Iowa and western Illinois show that there are many other east-west valleys which show the same asymmetry. Thus this is a regional problem.

No attempt has been made to evaluate the influence that difference in insolation received by north and south-facing slopes has had in the development of the two basins although from field observation it is readily apparent that the north-facing slopes remain frozen and are covered by snow for a greater period of time than the south-facing slopes. North-facing slopes may, therefore, experience a slightly shorter period of erosion each year.

So far in this discussion it has been assumed that the shapes of these valleys are due entirely to erosional processes. This may not be true, however. From field observations it was noted that in most cases the northern slopes of the major stream valleys were completely covered by loess. In ascending these slopes in very few instances could drift be seen in the roadcuts. On the other hand, drift was usually exposed in the roadcuts traversing the south valley slopes. Kay (1943, p. 54) points out the effect loess has played in modifying erosional topography. It is suggested here that the asymmetry in drainage basin area and valley side slopes may be the result of greater amounts of sand and silt being deposited and trapped on the northern (leeward) valley sides. The loess was blown from the Iowa River floodplain, which lies to the north of the two basins (Lyon, Handy and Davidson, 1954). As the loess was transported to the south, it was draped over the intervening drainage divides in an asymmetrical fashion, thicker on their south sides and thinner on the north sides. The greater accumulations on the south slopes of the divides reduced the relief on this side (i.e., north) of the stream valley. Owing to the thicker accumulations of loess on the north valley sides, more material was moved by colluviation from this direction down to the major streams, forcing them against their southern banks, resulting in undercutting and oversteepening of south valley walls.

The asymmetry of these valleys is probably the result of a combination of causes: 1) the inequal distribution of loess, 2) the influence of the regional slope, and 3) the differences in insolation received between the north and south slopes.

Figures 4 and 7 show that Old Man Creek and Clear Creek conform very closely to the laws of stream numbers and basin areas. Old Man Creek and the first four orders of Clear Creek were also found to fit Strahler's law of total stream lengths (Fig. 6). The discrepancies in the lengths of the fifth order streams of Clear Creek's basin are possibly due to the invasion of the northern portion of the basin by the Iowan glacier and consequent disruption of the drainage (Fig. 1), which may have brought about a narrowing of the basin and a shortening of all fifth order streams extending to the north of the major drainage line.

In terms of the above parameters and limited geologic investigations, it would appear that these basins are not "misfit" but are morphometrically more or less normal or usual. Possibly these valleys are polygenetic, being both erosional and depositional in character.

Acknowledgements

The authors wish to express appreciation for assistance provided by personnel of the Iowa and Johnson County offices of the U. S. Soil Conservation Service, and to the Water Resources Division of the U. S. Geological Survey.

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