INTERGLACIAL CONSEQUENT VALLEYS OF CENTRAL NEW YORK.

JOHN S. WOLD.

ABSTRACT. Unique consequent valleys on the glacially oversteepened walls of central New York "through valleys" are described and presented as a further criterion of multiple glaciation in that area.

INTRODUCTION.

IN view of the well established fact of multiple advances of the Pleistocene glaciation in the Middle West, it seems fair to conjecture that central New York should have a similar history of ice invasions. It has proved difficult, however, to discover positive evidence of such a succession. The problem has been approached from various angles. Carney (1907) asserted that a compact blue till, overlain by a yellow, weathered till, represented deposits of two different invasions. Later (1909) he admitted the difference in coloration to be no definite proof. von Engeln (1929) argued that both tills were from the same glaciation, that their difference resulted from manner of transport and deposit. Maury (1908), Tarr (1909), and Baker (1913) inferred multiple glaciation of this region on paleontological evidence. Their inferences were based on findings of fresh-water shells in a Cayuga Lake delta, and the leaves of an arctic willow in glacial drift at Watkins Glen, which they thought could be correlated with similar species found in the interglacial beds of Ontario. The presence of gorges similar in form to the postglacial gorges, but unlike them in that they are either drift-filled or possess more weathered rock walls, has been used as a basis for deducing more than one period of

Am. Jour. Sci.—Vol. 240, No. 9, September, 1942.
42

glaciation. (Tarr, 1902; Matson, 1904; Rich and Filmer, 1915.) The possibility that these gorges might be preglacial was dismissed in at least two specific instances in discoveries of weathered gravel deposits derived by stream erosion of glacial deposits. These deposits were considered to have been water transported interglacially to their present site immediately before the area was covered by ice of the last advance (von Engeln, 1929). Such rejection of preglacial origin may be regarded as support for the validity of inferences of more than one glaciation on the basis of interglacial origin of these gorges.

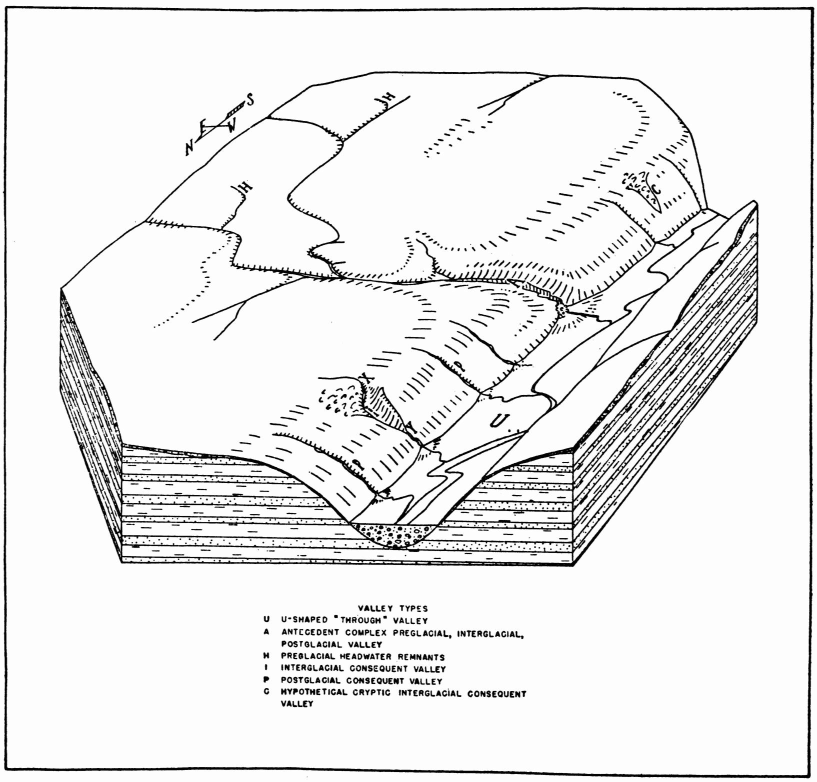
Interpretation of the drift-filled gorges as of interglacial development implies change of base level for streams tributary to the major north-south valleys of the region. Differential glacial erosion of the north-south valleys caused the east-west tributaries to be left as hanging valleys. This hanging-valley relationship, brought about by the glacial lowering of base-level, permitted the cutting of gorges in their lips by later stream erosion. Such gorges must thus have been developed after at least one glaciation. Since some of the hanging-valley-lip gorges are partially or wholly filled with drift, they must have been formed prior to the last glaciation.

Glacial deepening of the major north-south valleys was accompanied by straightening and steepening of their preglacial, late mature slopes. This steepening made new slopes on which small, consequent stream courses were established. Such postglacial consequents, formed on the steepened slopes of the last advance, are relatively numerous and easily recognized. If glacial deepening was primarily effected by any earlier ice advances then similar consequent streams should also have been developed interglacially. Subsequent glacial erosion would be expected to have left hanging all such identifiable consequent valleys, or if severe enough to have completely eroded them. It is the purpose of this paper to demonstrate the identification of valleys inferred to be of such interglacial consequent origin, to describe them, and to discuss their significance in the glacial history of the region.

SITE.

The area of this study lies generally in the Finger Lakes region of south central New York State, near the northern boundary of Pennsylvania. More particularly, it lies at the head of Cayuga Lake, the largest of these bodies of water. The area embraces the Ithaca, Dryden, Waverly, and Owego, New York, 15 minute quadrangles of the U. S. Geological Survey.

The topography, in general terms, may be characterized as rugged. Throughout the area interbedded Devonian shales and sandstones, with a gentle regional dip to the southwest, crop out, or immediately underlie the Quaternary deposits. The uplands rise from an average elevation of 1200-1400 feet at Ithaca to 1600-1800 feet nine miles south. Conjecturally these latter elevations were the site of a preglacial divide between drainage flowing to the north and that flowing south to the Susquehanna. Farther south the uplands have more moderate elevations.



TYPES OF VALLEYS.

The larger valleys of the glaciated central New York plateau region are characteristically U-shaped (U, Text Fig. 1). This feature is especially prominent in the north-south valleys to which the genetic term "through valleys"[1] has been given. Reaming out by the ice to produce the U-form involved great increases in valley depths, steepening of the valley walls, truncation of spurs, straightening of the preglacial, late mature slopes, and the reduction of headwater divides. At the same time, the uplands generally were little modified from their preglacial contours. The contrast in aspect arising from this difference in glacial modification is the basic circumstance responsible for the great variety of valley types now present.

Many of the larger preglacial valleys tributary to the main north-south channels experienced ice erosion. Bottom currents in the ice sheets were diverged into the channels of Six Mile Creek, Fall Creek, Cayuga Creek, and other large tributary streams, while the main ice mass moved in a general north or northeast to south or southwest direction. (von Engeln, 1934-1935; Demorest, 1939.) Lesser bottom currents, at various angles with the main direction of movement, also grooved the smaller upland valleys and deepened cols along inter-stream divides. It appears, however, that small, high altitude, preglacial valleys oriented at right angles to the main direction of ice motion suffered little modification. Such remnants of the preglacial drainage systems as persist are, therefore, on the uplands. (H, Text Fig. 1.)

Between the relatively flat expanses of the glacially little modified uplands, and the floors of the glacial troughs, are the oversteepened slopes. Into these slopes are notched the channels of the successively regraded preglacial streams. (A, Text Fig. 1.) On the slopes are found independent consequent stream valleys which fit into no previously recognized category. These obviously belong to neither the deeper through valleys nor the remnant preglacial and regraded valleys of the uplands. Such consequents are of two types: (a) those occupying straight, shallow, ungraded valleys commonly extending the full length of the steepened slopes, and inferred to be postglacial consequents, and (b) deeper, more mature valleys cut into the slopes and inferred to be interglacial consequents.

[1] "Through valley (name suggested by Prof. W. M. Davis) because they extended uninterrupted through from one drainage system to another." (Tarr, 1909, p. 17).

DESCRIPTION OF TYPE INTERGLACIAL AND POSTGLACIAL CONSEQUENT VALLEYS.

The eastern walls of the Cayuga through valley for several miles south of Ithaca are the site of numerous parallel, ungraded stream courses. Because they are of an intermittent character, and because their valleys are so numerous and superficial, these streams were either too small to show or deemed of too little importance for record in the U.S.G.S. topographic survey of the area in 1900. They are inferred to be postglacial consequents.

Another type of valley, somewhat resembling the inferred postglacial consequents, occurs on the same oversteepened slopes. Valleys of this second type also extend parallel to the inclination of the glacial slope, but are broader, deeper, have a more mature development, and usually are partly moraine-filled. They are inferred to be interglacial consequents.

Characteristic examples of both types occur two and one-half miles south of Ithaca and one-half mile south of Buttermilk Falls. The shallower, inferred postglacial valley (Plate I, Fig. 2, and P, Text Fig. 1) is approximately seventy-five yards north of the larger, inferred interglacial valley (Plate I, Fig. 3, I, Text Fig. 1). The vertical descents of the two streams are the same, but the volume of water carried by the shallower is much larger. Both streams flow in a general west-northwest direction from their headwaters above 1000 feet A.T. to their lowest courses at Inlet Creek, two-thirds of a mile distant, 420 feet A.T. The steepening angles of inclination of the glacially modified slopes have determined unique profiles for these streams. The successive declivities divide their valleys, observed along the top edges, into three major sections.

HEADWATERS.

The uppermost headwaters of both these streams are found on the gentle, upland slopes of what is interpreted to be the valley floor of preglacial Cayuga River. Here the channels are cut into the ground moraine deposited by the last ice invasion. Both headwaters extend from their extremities above 1000 feet A.T. down to 800 feet A.T. There a steeper gradient and a thinning of the moraine have enabled erosion to bedrock with the formation of a series of small, caprock, step falls.

MIDDLE COURSES.

At 780 feet A.T. a slope of 15 to 20 degrees is reached. This steepening is reflected in a greater erosive capacity of both streams. Valley *P*, inferred to be postglacial, assumes the form of a shallow, bedrock channel. Its depth nowhere exceeds two to three feet; its width averages eight to ten feet. (Plate I, Fig. 2.) Structure in this middle section plays an increasingly important rôle downstream in locally determining the valley form. Jointing, principally, has deviated the stream for short stretches from its original orientation. Nevertheless, the stream follows essentially the inclination of the slope. There is a conspicuous absence of moraine in the rock cut gorge of *P*. Although the depth increases downgrade to ten to fifteen feet, the width remains almost constant except where frost action has formed small amphitheatres.

The headwaters of valley *I*, inferred to be an interglacial consequent, intersect the wall of a broad, V-shaped trough at 780 feet A.T. (X, Text Fig. 1). At the point of junction this trough is approximately twenty feet deep and fifty feet wide. Its walls and floor are covered with morainic fill. Sampling of the moraine discloses that it is similar to the glacial deposits in the headwater areas. From the point of junction (X, Text Fig. 1) to the 520-foot contour, stream *I* remains within the trough. Exposures inferred to be those of an old rock gorge may be found in this section at various points along the sides of the trough. (Upper left corner, Plate I, Fig. 3.) The valley floor here is a bedrock exposure two to three feet in width. The walls are composed of slope wash overlying moraine. From all appearances the present stream has, to date, been able only to clear out moraine and to excavate a V-shaped valley in drift down to the old trough floor. In no section is the moraine fill completely cleaned out. While the trough gradient remains fairly constant, the declivity of the glacially modified Cayuga Valley wall becomes so steep at 520 feet A.T. that it there intersects the trough floor leaving the trough hanging. (Y, Text Fig. 1.)

LOWER COURSES.

An increased gradient at 520 feet does not induce any general change in the form of the inferred postglacial valley *P*. Its gorge continues to the Cayuga Valley floor as a series of step falls and joint-controlled meanders (Cole, 1930). Change of gradient from the oversteepened slope to the almost flat, aggraded, valley floor has formed an alluvial fan at the gorge mouth.

A similar moraine-free, joint-controlled gorge and alluvial fan in the lower courses of stream *I* so closely resemble the corresponding features of the same section of valley *P* that they must be classified alike.

COMPARISONS AND INFERENCES.

Development of both valleys described above, because of their proximity, has been conditioned by the same rock structure and, postglacially, by the same slopes. The headwaters are noted to be, similarly, superficially incised into ground moraine of the last ice invasion. It has seemed reasonable, therefore, to assume that in their present expression they are postglacial.

In contrast to the shallow, fresh, moraine-free rock-channelling of valley *P*, the less mature middle courses of valley *I* are represented by a deep moraine-filled trough. It is evident that this stream with its lesser flow would not have been able to erode postglacially a larger valley in rock than that of the inferred postglacial stream which has greater volume. The presence of masses of moraine in the larger trough, which the stream has not been able to clear out, indicates that the trough was present prior to the last ice advance. This points either to an interglacial or to a preglacial origin.

Since the gorge-valley cross section of *P* varies throughout with the gradient of the slope into which it is cut, and since the valley descends directly down these slopes, it must be considered consequent on them. It, therefore, must postdate the last glaciation which, in some degree, modified these slopes. Since moraine fill is not to be found in any section of this valley, its formation is indicated as postdating the last ice invasion which deposited the moraine. Stream valley *P* is, therefore, inferred to be a postglacial consequent valley.

All recognized preglacial valleys, having a broad, mature form, terminate in wide openings scalloped into the top rim of the glacially oversteepened slopes of the major U-shaped valleys (A, Text Fig. 1). The trough channel of stream valley *I* is not broad enough or deep enough to have left such a scallop in the oversteepened slope. Its apparent age and its orientation are at variance with recognizable preglacial, dendritic drainage patterns. The inclusion of the valley with those of preglacial origin, therefore, seems precluded. This relegates its development to interglacial times.

The fact that the trough of valley *I* parallels the inclination of the slope (that is, descends it by the straightest course) and is apparently of interglacial origin, with no preglacial valley connections, seems to indicate that it was formed by drainage consequent to the slope. If, as assumed, a pre-Wisconsin ice invasion overdeepened the Cayuga Valley, it must have left oversteepened rock slopes on which consequents formed as they have postglacially. Since interglacial time is inferred to have been longer than postglacial, any consequent, descending such an oversteepened slope, should have been able to cut a deeper, more mature valley than could have been cut by postglacial streams of the same size. By integration of drainage the number of consequents on a given slope should decrease with maturity. The inferred interglacial trough valley is much larger than any of the postglacial consequent valleys, and the proportion of inferred postglacial channels found over several miles of this slope is approximately five times that of the exposed inferred interglacial channels. Some of the latter, however, may be completely hidden under moraine fill (C, Text Fig. 1). It is therefore suggested that the moraine-filled trough described above, from the junction (X) at 780 feet A.T. to the hanging lip (Y) at 520 feet A.T., is of interglacial origin, and that it was formed by a stream consequent to an oversteepened slope left by pre-Wisconsin glaciation.

COMPARATIVE STUDIES.

Approximately as favorable slopes for consequent stream development must have been presented interglacially as postglacially if the main overdeepening and modification of topography resulted from pre-Wisconsin glaciation. Interglacial consequents should generally be present on such slopes. This was found to be the case. In the Buttermilk area, south of Ithaca, the slopes were apparently especially suited to consequent development. The outstanding characteristic of these declivities is their gradation from broad, preglacial, upland, valley slopes to the lower steepened "U" walls. The more gentle slopes above these walls serve as a drainage collection area.

FIG. 2

Moraine-free rock-channelling of the middle courses of inferred postglacial consequent valley *P*. See Text Fig. 1. Photograph taken October 1939. While the streams *I* and *P* are inferred to be of the same age their valleys are not of the same maturity. This section of *P* is more mature than that of *I* (Fig. 3) because of greater erosive capacity due to flow volume.

FIG. 3

V-shaped trough of inferred interglacial consequent valley *I*. Note relative volumes of water in this stream and that of Fig. 2. Both photographs were taken on the same day, October 1939. The old inferred interglacial rock-gorge walls are exposed in the upper left corner. At this point the present reinstated stream has excavated ground moraine to the old interglacial rock-valley floor.

While the steep walls of through valleys transecting a divide region as a rule do not have sufficient drainage area for consequent stream development, less intensely glaciated walls of preglacial valleys (not through valleys) usually have conditions unfavorable for the identification of interglacial consequent valleys. Postglacial consequent development is found on the more gentle, western, glacial slopes of Cayuga Valley south of Ithaca. Such streams due to the lesser slope gradient have not been able to cut rock gorges of the size described as present on the markedly steepened, eastern walls. Any interglacial consequent valleys on such slopes must, therefore, have been of the same superficial nature. Their channels would easily have been completely moraine masked, or the moraine into which they were cut removed by a later ice invasion. It is probably because of such mantling or erosion that interglacial consequent developments have not been found on these slopes.

Only certain glacially oversteepened slopes seem favorable for this consequent development. These are essentially those U-valley walls above which are found broad, preglacial valley slopes to constitute a somewhat extensive drainage area. In central New York, outside the region of this study, areas of such favorable slopes are found notably on the steepened slopes of many of the through-valley extensions of the Finger lake basins.

SIGNIFICANCE IN THE GLACIAL HISTORY OF THE REGION.

The presence of consequent streams, as described, on the oversteepened slopes of the major north-south valleys of central New York would seem to be further indication that these slopes were formed by glacial erosion and not by rejuvenation through regional uplift. The form and development of the consequents points to drainage superposition on slopes exposed immediately after the ice erosion and retreat of glaciers. If interglacial consequents existed, as postulated, then steepening and deepening preceded the last glaciation and was due principally to glacial erosion.

The truncation of the lower sections of the interglacial consequents supports the theory that the main overdeepening of Pleistocene glaciation was accomplished in pre-Wisconsin time. Since the effectiveness of ice erosion is assumed to be proportional to the thickness of the ice, the major glacial modification should be centered on the axes of the valleys. It is inferred that the Wisconsin ice invasion was of much less competence because of less volume. It, therefore, eroded effectively only at the level of the lower portions of the interglacial consequent valleys, which had previously been incised to an approximately constant depth throughout their length.

While interglacial consequent valleys indicate the invasion of at least two glaciations, there remains the possibility of greater multiplicity of advances. Earlier interglacial consequent channels may have been completely obliterated by pre-Wisconsin ice invasions. The channels identified as interglacial consequents, however, showed no evidence of having undergone more than two cycles of erosion, interglacial and postglacial. But the absence of consequents of more complex history is indeterminate for the question of greater multiplicity.

The author is indebted to Prof. O. D. von Engeln, Cornell University, for the suggestion of this problem, and for his many helpful criticisms which have made its development possible.

WORKS TO WHICH REFERENCE IS MADE.

Baker, F. C.: 1913, *Interglacial Records in New York*, Science, new series, Vol. 37, pp. 523-524.

Carney, F.: 1907, *Pre-Wisconsin Drift in the Finger Lake Region of New York*, Jour. Geol., Vol. 15, pp. 571-585.

————: 1909, *The Metamorphism of Glacial Deposits*, Jour. Geol., Vol. 17, p. 486.

Cole, W. S.: 1930, *The Interpretation of Intrenched Meanders*, Jour. Geol., Vol. 38, no. 5, pp. 423-436.

Demorest, M.: 1939, *Glacial Movement and Erosion*, Amer. Jour. of Sci., Vol. 237, pp. 594-605.

Matson, G. C.: 1904, *A Contribution to the Study of the Interglacial Gorge Problem*, Jour. Geol., Vol. 12, pp. 133-135.

Maury, C. J.: 1908, *An Interglacial Fauna Found in Cayuga Valley and its Relation to the Pleistocene of Toronto*, Jour. Geol., Vol. 16, pp. 565-567.

Rich, J. L., and Filmer, E. A.: 1915, *Interglacial Gorges of Six-mile Creek at Ithaca, New York*, Jour. Geol., Vol. 23, pp. 59-80.

Tarr, R. S.: 1902, *Physical Geography*, New York.

————: 1909, *Geol. Atlas of the United States, Folio 169, Watkins Glen-Catatonk, New York*, p. 26.

von Engeln, O. D.: 1929, *Interglacial Deposit in Central New York*, Bull. Geol. Soc. Am., Vol. 40, pp. 469-480.

————: 1934, *The Motion of Glaciers*, Science, Vol. 80, pp. 401-403.

————: 1935, *The Motion of Glaciers*, Science, Vol. 81, pp. 459-461.

VANDERBILT, TEXAS.