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Pleistocene Mountain Glaciation, Northern Vermont

ABSTRACT

Lateral moraines, end moraines, cirques, and outwash plains together demonstrate the former presence of local valley glaciers in the Green Mountains of northern Vermont. Two phases of valley glaciation are recognized. The earliest phase is represented by end moraines and stagnant ice features that are graded to outwash plains that in turn can be traced into deltas of Laurentide proglacial lakes. Comparison of delta elevations indicates that the moraines of the earliest phase are generally the same age but with minor differences. The second phase is indicated by cirque moraines and outwash plains. The earlier phase is definitely late Woodfordian, but the absolute age of the later phase is uncertain. Although valley glaciers are recognized, the possibility of an ice cap in northern Vermont is considered unlikely.

INTRODUCTION

During the course of study of Laurentide proglacial lakes in the Champlain Valley, relatively large deltas were found in several tributary valleys in the adjacent Green Mountains. The large size of the deltas in relatively small valleys suggested an exceptionally large amount of sedimentation. Further investigation showed that in many cases the deltas could be related via outwash plains to end moraines and stagnant ice deposits upstream, which necessarily implies that ice masses in the valleys were separate from the Laurentide ice sheet. Amphitheater-like basins at the heads of valleys (cirques) with bedrock-controlled lakes (tarns), along with lateral and end moraines conclusively demonstrate that the ice involved was active and confined to the valleys and, therefore, could be referred to local valley glaciers.

PREVIOUS WORK

Some of the earliest studies of Pleistocene deposits in the Green Mountains endorsed the concept of local glaciers as opposed to a "foreign" ice sheet as the responsible agent (Chalmers, 1897; C.H. Hitchcock, 1908; E. Hitchcock, 1861; Upham, 1895). However, such views amounted to statements of belief reflecting the changing concepts of the times rather than any evidence by modern standards. The first known documented case of valley glaciers was presented by Hubbard (1917) in southern Vermont. At about the same time, Goldthwait (1916) stated, on the basis of his field review of earlier reports, that there was no evidence for independent Green Mountain glaciation. Such a view, coming as it did from a recognized authority on New England mountain glaciation, has generally prevailed until the present time. Cirque topography has been recognized on Jay Peak by Washburn (*in* Flint, 1951) and on Mount Mansfield by Christman (1956), but in the latest comprehensive accounts of Vermont glacial geology by Stewart (1961) and Stewart and MacClintock (1969), no mention of local glaciation is made. Another old but still debated concept is that of a local ice cap in the northern New England Appalachians, including the Green Mountains. Flint (1951) and McDonald (1967) present up-to-date discussions of the subject, including extensive reviews of the literature. Although there is evidence for and against such an ice cap, Flint (1951, p. 29) concluded that "... it is not unlikely that such a center [for an ice cap] existed in northern Vermont."

EVIDENCE FOR VALLEY GLACIERS

Figure 1 shows the general location of the area studied and the distribution of moraines and pertinent deltas. The term "moraine" is used here in reference to deposits of sand and gravel, or till, or both, which have constructional topographic expression, and which can be inferred to have formed in the terminal zone of valley glaciers. Outwash plains, omitted from Figure 1 for simplicity, are recognized as sand and gravel deposits with terrace-like forms that originate at moraines and are graded to channels associated with the moraines. In most cases, deltas are indentified in the field as bench-

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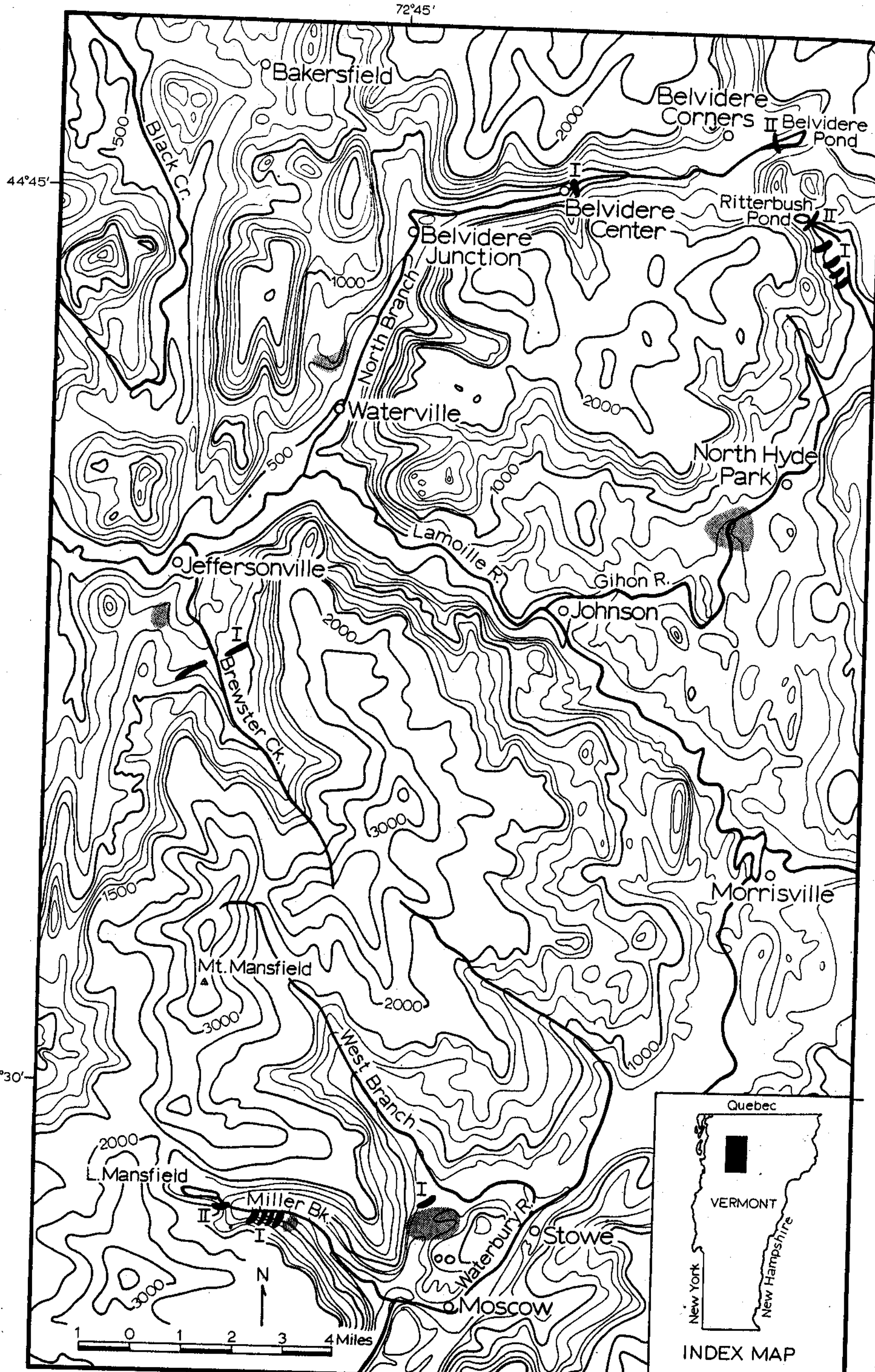

Figure 1. End moraines (solid) and deltas (stippled) related to Mountain glaciation in northern Vermont. Earlier (I) and later (II) phases of glaciation are indicated.

like land forms composed of sand and gravel overlying deeper-water lacustrine silt and clay. In some cases, it is difficult to eliminate the possibility that the clastic sediments unconformably overlie the lacustrine sediments, and in other cases to verify the lacustrine sediments beneath suspected deltaic sand and gravel. Nevertheless, these difficulties are not serious, and most deltas can be positively indentified.

Some of the best evidence of valley glaciation occurs in the valley of Miller Brook, west of Stowe (Fig. 1). The Miller Brook Glacier constructed a moraine with kame and kettle topography in a broad reach of the valley, approximately .75 to 1.25 mi downstream from Lake Mansfield. A delta (elevation 900 to 920 ft)[1] was constructed immediately downstream from the moraine (Fig. 1). The lake in which the delta developed was a Laurentide proglacial lake, as discussed below.

A younger glacial event in Miller Brook Valley is recorded by well-developed lateral and end moraines about .25 mi downstream from Lake Mansfield. The end moraine consists of a single ridge of till, 50 to 70 ft higher than the adjacent terrain. The ridge is breached by Miller Brook and is best developed and preserved in the south side of the valley where it can be traced into a distinct lateral moraine.

Lake Mansfield, at the head of Miller Brook, is situated in a closed bedrock depression in the floor of an amphitheater-shaped basin; the basin is undoubtedly a cirque and were it not for artificial impoundage, Lake Mansfield (elevation 1140 to 1160 ft) would be a classic tarn.

Another valley which contains an extensive record of Mountain glaciation is that draining Ritterbush Pond, about 3.75 mi north of North Hyde Park. No name has been given to the stream in this valley, but for convenience it is informally referred to here as Ritterbush Valley. Ritterbush Pond (elevation 1041 ft) is probably a tarn, although no proof of the bedrock threshold could be found. At the east end of the Pond is a series of till end moraine ridges that are traceable southward into lateral moraines. An extensive complex of gravelly kame and kettle deposits marks an older end moraine farther downvalley (Fig. 1). This moraine is correlated with a delta (elevation 840 to 860 ft) southwest of North Hyde Park (Fig. 1).

[1]Elevations cited in the text are from topographic contour maps, which in some cases necessitate stating the limiting contour elevations.

In the northwestern corner of the area is Belvidere Pond (elevation 1137 ft) which is probably a tarn. An end moraine occurs at the western margin of Belvidere Pond, and a second at Belvidere Center (Fig. 1). The latter moraine probably is related to a delta (elevation 720 to 740 ft) near Waterville, although a slightly higher deltaic? surface near Belvidere Junction, and not the Waterville delta, may correlate with the moraine.

In the Brewster Creek Valley near Jeffersonville is a moraine that definitely can be correlated with a 700- to 720-ft delta. However, other moraines and a definite cirque cannot be identified in the valley. It is possible that the Brewster Valley moraine was deposited by a remnant mass of ice left behind by the retreating Laurentide ice sheet. A similar relationship exists in the West Branch Waterbury River Valley where a possible moraine appears to be related to a delta (800 to 820 ft elevation), but no conclusive evidence of an independent glaciation has been found.

On the west side of Mount Mansfield are broad gravel surfaces that resemble outwash plains and seem to be associated with extensive areas of kame and kettle topography. Because it is impossible to conclusively demonstrate that these outwash deposits were formed by glaciers separate from the Laurentide ice sheet, no further consideration is warranted here.

In many places in the area are deltas at about the same elevations as those discussed above, but reconnaissance investigation failed to show related moraines and outwash plains. It is possible that either Laurentide ice remnants which left no moraines provided detritus for the deltas, or that more detailed study would reveal moraines. Also, in many places in the mountains in this area are cirque-like forms, in addition to those discussed above, which have not been studied due to their difficult access and because a more intensive investigation was beyond the scope of the present study.

EVIDENCE AGAINST A GREEN MOUNTAIN ICE CAP

As pointed out by Flint (1951, p. 29) the evidence for a local ice cap as opposed to a foreign (Laurentide) ice sheet is necessarily very obscure. No definite, direct evidence for or against a local ice cap has been found in the present study. Ice marginal deposition in the Green Mountains was apparently restricted to valleys, which is not to be expected with an ice cap.

The valley glaciers described above were contemporaneous with proglacial lakes which were dammed by Laurentide ice margins west of the Green Mountain axis. Except for local valley glaciers, it appears that the upland areas were ice-free, while Laurentide ice occupied the Champlain Valley and lower reaches of its tributaries. Thus, any ice cap in the study area necessarily must have been in existence prior to the times of valley glaciation and Laurentide deglaciation considered here. It seems likely that during the initial waning of the Laurentide ice sheet, upland topography rather than regional ice surface slopes may have controlled the direction of ice movement. Thus, hypothetically at least, ice movement may have been outward, away from the higher terrain. The question of whether or not such movement, if in fact it ever occurred, constitutes an ice cap is a semantic one, but there does not appear to have been any ice mass separate from the Laurentide ice sheet in the general sense of an ice cap. It is, however, possible that some of the features attributed to an ice cap by others were derived from local valley glaciers or from a restricted ice cap outside of the area studied.

SUMMARY AND CONCLUSIONS

Pleistocene Green Mountain valley glaciation, independent of the Laurentide glacier, is represented by end and lateral moraines, outwash plains, and cirques. In many valleys, two phases of valley glaciation can be recognized (I and II, Fig. 1). The earlier phase is indicated by end moraines (labeled I in Fig. 1) that are associated with deltas having similar elevations. The similarity of delta elevations suggests that the related moraines were roughly contemporaneous, although slight age differences are likely. West Branch Waterbury River Valley moraine and Ritterbush Valley moraine complex I probably formed at the time of Pleistocene Lake Mansfield (Stewart, 1961, p. 95). Miller Brook Valley moraine complex I is associated with a delta that is slightly higher and therefore slightly older than Lake Mansfield. North Branch Lamoille River Valley moraine I and the Brewster Valley moraines are related to deltas below Lake Mansfield and therefore are slightly younger than deposits associated with Lake Mansfield. Although the information is insufficient to discern any definite trends, there is a suggestion that the deposits of morainic phase I may be slightly older northward.

The second phase of Mountain glaciation (phase II, Fig. 1) is definitely younger than the first phase as shown by relative positions of the different moraines in the valleys, and by the phase II outwash plains which partially dissect phase I moraines in some places. Unfortunately, the phase II outwash plains cannot be related to other deposits which might give some indication of time of deposition.

There is no evidence to directly determine either the absolute ages of phases I and II, or the time span separating the phases. Phase I is generally equivalent to the late Pleistocene Laurentide ice sheet deglaciation which in this area probably is on the order of 12,000 to 13,000 years old, judging from age dates and discussions presented by Connally and Sirkin (1969) and McDonald (1968). The age of phase II is unknown, although perhaps not much younger than phase I.

ACKNOWLEDGMENTS

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Pleistocene Mountain Glaciation, Northern Vermont: Discussion

In his recent report concerning Mountain Glaciation in Vermont, Wagner (1970) noted that the latest comprehensive accounts of the glacial geology of that state by Stewart (1961) and Stewart and MacClintock (1969) made no references to local glaciation. The omission of this subject from these reports was not an oversight inasmuch as no conclusive evidence of Mountain Glaciations was found during the 11-yr survey of the state completed in 1966. The participants in the mapping program were cognizant of the earlier reports (Flint, 1951; Christman, 1956) that had recorded evidence of local glaciation. The evidences cited in these reports were studied, but were found to be inconclusive.

The assumption by Wagner (1970) that Laurentide ice activity could not have occurred on the east side of the Green Mountains after the active portion of the glacier had receded to the west cannot be substantiated. The last recorded glaciation to move across the Green Mountains invaded from the northwest (Stewart and MacClintock, 1969). The ice piled up on the west side of the mountains until its thickness was great enough for it to cross the summits. Undoubtedly the first ice to cross the mountains moved down the eastern slopes in lobes that were probably confined to the valleys. More importantly, however, insofar as erosion and deposition are concerned, was the waning of the glacier. Active recession by ablation thinning could occur only in the upper, thicker portion of the glacier. The lower ice, however, could not retreat because it was trapped between the mountains (Stewart, 1961, p. 25-26). The ice that remained between the mountains after the upper portion had receded was thick enough to produce independent motion wherever movement was possible. The last remnants of these ice masses were confined to the valleys, and they no doubt moved down and receded up the valleys similar to valley glaciers. The valley remnants could have produced moraines, but they could not have eroded cirques.

Outwash plains are described by Wagner (1970) as sand and gravel deposits with terrace-like form; however, he does not describe the structure of the gravel within the deposit. All of the deposits that Wagner describes as outwash plains have been classified on the Surficial Geologic Map of Vermont (Stewart and MacClintock, 1970) as kame gravel, the majority of which are kame terraces. They are so designated because of their topographic form, their ice-contact (slumping) structures, and their unusually high content of large, ice-rafted boulders. These features can be observed in stream valleys, highway cuts, and in numerous gravel pits excavated into them. It is assumed that Wagner interprets these deposits as valley trains that were formed by water from melting glaciers upstream. Our interpretation contends that the deposits were formed between the ice and the valley wall when ice still occupied the valley.

Wagner stated that he identifies deltas as bench-like forms composed of sand and gravel overlying lake silts and clays. The most common lake sequence in north-central Vermont contains clay or silty clay, or both, at the bottom with sand above the silty clay and gravel commonly at the top. The thickness of the clay or silty clay, or both, is often about equal to the sand, but the gravel thickness is much less. The sand and gravel are horizontally bedded, and they may contain cross-bedding within the layers, but no long, gently dipping beds that characterize a delta. Beach gravel is sometimes found above the sand along the valley walls. The classification of many of the deltas by Wagner is, therefore, questioned.

Lake Mansfield does occur in a cirquelike depression at the head of Miller Brook. The shape of the basin, however, does not conclusively prove that it is a cirque. Investigations made during the surficial geology mapping program showed that the walls of most of the basin were joint faces and no evidence of glacial abrasion was evident.

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It is not the intent of this paper to imply that the writer is certain that local glaciation did not occur in Vermont. The possibility is a most interesting problem. It is believed, however, that the evidences cited by Wagner do not conclusively prove Mountain Glaciation.

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Pleistocene Mountain Glaciation, Northern Vermont: Reply

Through the years a variety of depositional agents, including floods, Mountain Glaciers, ice caps, and a foreign ice sheet, have been proposed to explain surficial deposits in New England. In recent times, however, except for features formed by Mountain Glaciers in a few, small, upland areas, most such deposits are assumed to be related to the Laurentide ice sheet. My report of Mountain Glaciation in the northern portion of the Green Mountains not only revives an old concept for Vermont, but also adds to the existing evidence for a more complex late Pleistocene history in upland areas in New England than afforded by the popular model of Laurentide glaciation alone. Considering the relatively low elevations of cirque floors in the Green Mountains, the apparent lack of comparable valley glaciers in the higher and more massive White Mountains is remarkable, if not incredible. The fundamental issue raised by Stewart in his Discussion is, I believe, whether or not the evidence I cited for Mountain Glaciation is conclusive. My interpretation of Mountain Glaciation is based on the occurrence in northern Vermont of end and lateral moraines, outwash plains, and cirques, all so similar to comparable features I have seen in the Rocky Mountains, the Coast Ranges in the Yukon Territory and Alaska, and the Alps, that I regard the evidence overwhelming and in that sense conclusive. Stewart's skepticism appears to be based on mapping experience in Vermont and a concept of Mountain Glaciation that differs from mine, but not on his familiarity with my specific evidence.

Stewart writes (paragraph 2): "The assumption by Wagner (1970) that Laurentide ice activity could not have occurred on the east side of the Green Mountains after the active portion of the glacier had receded to the west cannot be substantiated." Nowhere in my original paper did I state or imply this assumption. In fact, I interpreted features in the West Branch Waterbury Valley (on the east side of the Green Mountain axis) as possibly due to a Laurentide ice remnant, contrary to the supposed assumption.

Stewart also gives (paragraph 2) his concept of Laurentide glaciation and deglaciation in the Green Mountains. He feels that Laurentide ice remnants could have acted similar to valley glaciers, flowing down and receding up valleys, and that the remnants could have produced moraines, but not cirques. Although I disagree with his concepts of glaciation and deglaciation, and suggest that ice capable of depositing moraines is capable of eroding cirques (avalanches are not common in the region, even on the steepest slopes), I believe the case for Mountain Glaciation should depend not just on cirques as Stewart apparently would suggest, but also on moraines and outwash plains, all essential components of Mountain glaciation. All of these features occur together in at least three Green Mountain valleys (Miller Brook, Ritterbush, and Belvidere Valleys).

Nowhere in his Discussion does Stewart consider the moraines I reported. A satisfactory alternative explanation of, for example, the spectacular Miller Brook Valley lateral- and end-moraine complex is difficult to imagine. As for outwash plains, Stewart indicates (paragraph 3) that the features I have called outwash plains correspond to the kame gravel unit on the Surficial Geologic Map of Vermont (Stewart and MacClintock, 1970), with topographic expression of kame terraces in most places. He further notes that I did not describe the sedimentary structures which, he believes, are ice-contact types. Stewart's views are inaccurate for several reasons. In the first place, the outwash plains in Miller Brook and Ritterbush Valleys occur in areas that are designated till on the Surficial Geologic Map of Vermont. Secondly, although I believe ice-contact structures are not uncommon in outwash plains, there are, nevertheless, no exposures in the outwash plains that reveal any structures. Thirdly, as stated in my original paper, the outwash plains are terrace-like; they resemble stream terraces, and in no

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way can they be confused with kame terraces. As I stated originally, the outwash plains originate at moraines, showing their glacial affinities.

Stewart questions (paragraph 4) the features I have described as deltas, although he does not make any specific remarks on individual features. The older phase of the multiple Mountain glacial chronology I proposed is established by correlation of moraines first with outwash plains, and, in turn, with deltas constructed in Laurentide proglacial lakes. Because such correlation involves some speculation and because stratigraphic evidence is lacking, the older phase of Mountain Glaciation is admittedly debatable. In fact, Gordon Connally (1970, written commun.) has convincing evidence indicating that older phase features in the Brewster Valley are more likely related to Laurentide ice. Although there may be some question about the older phase of Mountain Glaciation, the deltas themselves probably are identified accurately. Exposures in the deltas show sand and gravel overlying silt and clay, but no structures are visible due to exposure limitations. Elsewhere, however, deltaic structures in similar features are common, contrary to Stewart's view of their rarity. In any case, the deltas are not critical to the older phase of Mountain Glaciation, and no deltas are related to the younger phase. The delta question, then, seems irrelevant to the basic issue.

As I pointed out above, in addition to moraines and outwash plains, cirques help to establish Mountain Glaciation. Stewart regards (paragraph 5) the head of Miller Brook Valley as a "cirque-like depression," but suggests that the basin shape is in itself no proof of a cirque. I believe the head of the valley is so cirque-like that, in view of nearby moraines and an outwash plain, it probably is a cirque. According to Embleton and King (1968, p. 214) the principle features of a cirque include ". . . steep and shattered headwalls, a rock threshold sometimes capped with moraine, a rock basin enclosed by the headwalls and the threshold, and a ratio of height to length of about 1 to 3. Many cirques show a relationship with rock structure, but some do not." Except for moraine on the threshold (the moraine is located just downstream from the threshold), the head of Miller Brook Valley is a classic cirque by these standards. Its height to length ratio is about 2.6. Joints are abundant, but they are oriented along northwest-southeast and east-west maxima and do not directly control the shape of the basin. Glacial abrasion is not evident on the walls, [illegible] Stewart suggests it should be, but Embleton and King (1968, p. 204-205) point out [illegible] abraded surfaces are common on cirque floo[illegible] not cirque walls. I have found striae only on [illegible] floor of the cirque. Although not questioned [illegible] Stewart, the two other cirques I reported h[illegible] more or less similar characteristics.

To conclude, Stewart has not presented [illegible] evidence to warrant abandonment or revis[illegible] of my originally stated views. It seems certai[illegible] at least to me, that local glaciation did occur [illegible] the northern part of the Green Mountain[illegible] Since my original report, I have studied sever[illegible] promising-looking valleys in the region [illegible] have found no evidence of Mountain gla[illegible]tion. Apparently many upland valleys did [illegible] have local glaciers during the time of Mount[illegible] Glaciation in nearby valleys. C. G. Doll (197[illegible] written commun.) has found a well-develop[illegible] Mountain end moraine in the vicinity of [illegible] Peak, north of the area I studied. South of [illegible] Peak, A. L. Albee (1970, written commun[illegible]) noted Mountain end moraines in the valley [illegible] Wild Brook. In view of the widespread, al[illegible] somewhat sparse, distribution of Mountain [illegible]cial features, it seems likely that simila[illegible] dence for Mountain Glaciation exists elsew[illegible] in the region.

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Pleistocene Mountain Glaciation, Northern Vermont: Discussion

INTRODUCTION

The purpose of this paper is to discuss the features of the Brewster Valley that Wagner (1970) cited as evidence of mountain glaciation and to present an alternative history for mountain glaciation in northern Vermont. It is hoped that this discussion will help clarify local glaciation in Vermont and will be viewed as a compliment to Wagner's paper. This discussion in no way challenges the excellent work of Wagner and his students in documenting undoubted local glaciation in the Green Mountains.

In 1965 I served as a party chief for the Vermont Geological Survey in the state-wide surficial mapping project. The latter part of the summer was spent mapping the Mt. Mansfield 15-minute quadrangle that contains the Brewster Valley. In 1966, in an open-file report to the State Geologist of Vermont, and in 1967, in the symposium, Quaternary Geology of the Northeast, at the Geological Society of America northeast section meeting, I reported the results of the Mt. Mansfield project. Although both the report and the abstract carefully documented the lake history of the Lamoille Valley and the abstract contained the statement, "No indication of local cirque glaciation was observed on Mount Mansfield," neither was mentioned by Wagner.

After reading Wagner's paper I revisited the Mt. Mansfield region in October 1970, accompanied by Wagner and others, and found myself in complete agreement that features in the Miller Brook Valley, and probably others outside the Mt. Mansfield quandrangle, resulted from local, post-Laurentide mountain glaciation. However, both Wagner and I now agree that features in the Brewster Valley represent deglaciation by continental ice and accompanying glacio-fluvial activity, rather than local cirque glaciation. Figure 1 shows the Brewster Valley, situated on the northwest flank of Mt. Mansfield, draining Smuggler's Notch, and opening northward into the Lamoille Valley.

If Wagner's original interpretation of the Brewster Valley geomorphology had been accepted, the carefully documented lake history of the Lamoille Valley would have to be reevaluated. More important, a major post-Laurentide refrigeration would have to be postulated to account for the formation of a local glacier in this valley.

GLACIATION OF THE BREWSTER VALLEY

The Brewster Valley is oriented north-northwest on the south side of the Lamoille Valley. Striae reported by Christman (1959, Pl. 3) and Connally (1966, Fig. 2) show that continental ice moved southeast *up the Brewster Valley* toward Smuggler's Notch. No matter how deglaciation was accomplished, whether through backwasting as I believe, or through downwasting and stagnation, a new refrigeration would be required to reverse glacial flow, and initiate a north-flowing mountain glacier. No evidence supports such a climatic event.

LAMOILLE VALLEY LAKES

Because confusion existed in naming the various lake levels in the Lamoille Valley, I spent a great deal of time documenting these levels in the summer of 1965. As reported in the 1967 abstract (Connally, 1968), Lake Lamoille (840 ft), Lake Mansfield (740 ft), and Lake Coveville (660 to 640 ft) were present in the Brewster Valley and other tributaries to the Lamoille Valley. In my open-file report (Connally, 1966) I also reported a higher level at 1100 ft in the Brewster Valley.

Wagner (1970, p. 2468) has unfortunately followed the usage of Stewart (1961) rather than mine in the use of the name Lake Mansfield. Stewart misappropriated this name and applied it to a level traditionally referred to as Lake Lamoille (Merwin, 1908; Connally, 1966, 1968). Stewart and MacClintock (1969) have further confused matters by applying new names to the low levels discussed here and reapplying the names Lake Lamoille and Lake

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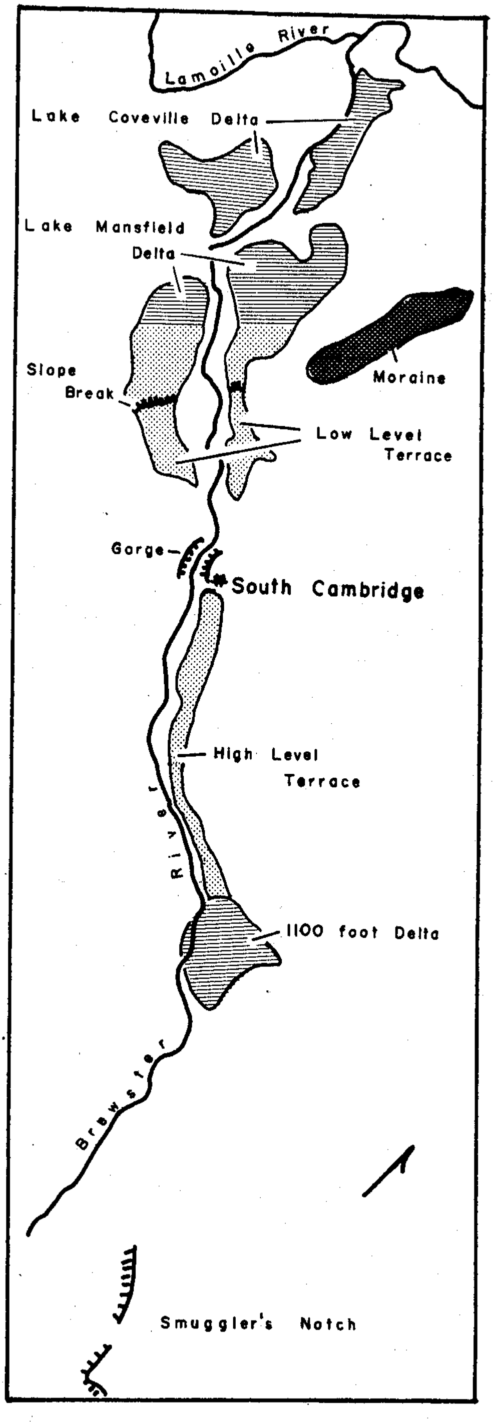

Figure 1. Terraces and deltas of Brewster Valley, Vermont.

Mansfield to inferred higher levels that probably never existed and certainly never existed in the Lamoille Valley.

GLACIAL GEOLOGY OF THE BREWSTER VALLEY

Figure 1 shows the Brewster Valley as it was mapped by me in 1965. The valley floor consists of a series of gravel terraces and deltas.

The highest feature in the valley is a delta that shows a slope break at 1100 ft. In 1965 foreset beds were well exposed in a fresh borrow pit. In 1970 only a suggestion of foreset beds could be seen, but bottomset sands were exposed at the base of the old pit.

From the base of the delta, at about 1000 ft, a smoothly graded, featureless terrace descends 1.5 mi to about 920 ft at South Cambridge. I relate this high-level terrace to a smooth bench at 840 ft that exists between a slope break on the low-level terrace and a belt of morainal topography that trends northward for 1 mi along the wall of the Lamoille Valley. This bench appears to be deltaic on the Mt. Mansfield 7.5 minute quadrangle, but augering in 1965 yielded olive-gray sand, typical of local ground moraine, covered by a thin layer of pebble gravel. Excavation may show this bench to be entirely deltaic, but in this Discussion, as in 1965, it is tentatively proposed as a fluvially eroded till bench related to Lake Lamoille.

At South Cambridge the Brewster River descends a bedrock gorge, the high-level terrace ends, and a lower terrace is encountered. The low-level terrace descends another 1.5 mi from about 820 ft below the gorge to 740 ft at the Lake Mansfield delta edge. About halfway between the gorge and the delta front there is an abrupt break in slope, with attendant erosional topography, from about 800 ft to 780 ft. The slope break is on a direct line with the morainal belt north of the 840-ft till bench, and Wagner originally equated these two features. The topographic map shows this break as a smoothly curved feature; however, it is composed of hillocks 20 to 30 ft high that are accordant and separated by northwest-trending valleys that grade continuously from an upper smooth surface, graded from 820 to 800 ft, to a lower smooth surface, graded from 780 to 740 ft. Wagner and I both interpret this slope break now as an erosional nip caused by a slight lowering of the Lake Mansfield outlet during, or possibly after, deposition of the terrace-delta sequence.

Below the Lake Mansfield delta there is a 640-ft delta, partly erosional, that I relate to Lake Coveville in the Champlain Valley. Wagner and I disagree about the existence of Lake Coveville in the Lamoille Valley, but that subject is beyond the scope of this discussion.

AN ALTERNATIVE HISTORY

Before presenting an alternative history it is necessary to discuss a delta at Belvidere Junction mentioned by Wagner (1970, p. 2467) as ". . . a slightly higher deltaic? surface. . ." west of Belvidere Center. This surface is an extensive outwash delta with kettles 20 to 40 ft deep. The delta is graded to the 840-ft Lake Lamoille level, as is the feature related to the Ritterbush Valley. Wagner felt that this level might correlate with the mountain glacier features at Belvidere Center and Belvidere Pond, even though he preferred a lower level. I suggest that the 840-ft pitted outwash delta does relate to the Belvidere Center and Belvidere Pond features.

Wagner proposed one local glacier related to my Lake Lamoille (his Lake Mansfield) level in the Ritterbush Valley and two local glaciers related to my Lake Mansfield, at Belvidere Center and in the Brewster Valley. Since the Brewster Valley features have been shown to be fluvial, the history of the entire Lamoille Valley becomes much clearer when both the Ritterbush Valley and Belvidere Center features can be related to Lake Lamoille.

I propose that the Laurentide ice retreated back from Mt. Mansfield, down the Brewster Valley, to a position marked by the morainal belt north of the Brewster River, damming the highest level 1100-ft lake in the upper Brewster Valley. When the ice margin retreated north of the Lamoille Valley, water levels dropped to 840 ft damming the Lake Lamoille of Merwin (1908) in the Lamoille Valley. At this time local patches of ice that were separated from the main ice mass and left in sheltered valleys shed sediment into Lake Lamoille. Some patches, such as those in Belvidere Pond, Ritterbush Pond, and Miller Brook became local, independent, mountain glaciers. The Brewster Valley was left ice-free, but received sediment from ice left in Smuggler's Notch. Opening of westward channels then lowered the water level to 740 ft, initiating Lake Mansfield, probably with a slight hesitation at 800 ft to cause the nip in the low-level terrace. Finally, ice retreated from the mouth of the Lamoille Valley lowering the water level to the 660- to 640-ft level that may correlate with Lake Coveville. With further lowering of water levels to Lake Fort Ann about 12,600 years B. P. (Connally and Sirkin, 1969), the Lamoille River began to incise its channel.

Whether or not local glaciers continued to be active throughout the duration of Lake Mansfield and Lake Coveville is problematical, but the margin of Laurentide ice did remain north and west of the Lamoille Valley into Coveville time (G.G. Connally, open-file rept., 1966, p. 26, and 1968). The lack of significant glaciofluvial or alluvial features after the escape of 640- to 660-ft waters precludes the continued existence of either continental or mountain glaciers after 12,600 yrs B.P. As active ice was present near Glens Falls, New York, about 13,200 yrs B.P. (Connally and Sirkin, 1971), I suggest that local glaciers were active between 13,200 and 12,600 yrs B.P.

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