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Ice Margins and Water Levels in Northwestern Vermon

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by

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PROGLACIAL LAKES IN THE LAMOILLE VALLEY, VERMONT

by

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INTRODUCTION

In what has become a classic reference for late Pleistocene drainage history in the Champlain Valley, Chapman (1937) delineated a series of lacustrine and marine water bodies associated with retreat of the Laurentide ice sheet. Successively lower levels of proglacial Lake Vermont extended progressively further northward, following the retreating ice margin. Finally, ice retreat allowed the influx of marine waters forming the Champlain Sea (Karrow, 1961). Numerous investigators working in the Green Mountain uplands have recognized the existence of local lakes, which were impounded between the highly irregular topography and the Laurentide ice margin, and which were partly contemporaneous with Lake Vermont. The publications by Connally (1966) and Stewart and MacClintock (1969, 1970) are recent examples.

This report summarizes research on Pleistocene proglacial events in the Champlain Valley and adjacent Green Mountain uplands. Numerous students at the University of Vermont provided assistance, including R. Switzer, C. A. Howard, Jr., W. R. Parrott, Jr., and B. P. Sargent. The use of data from dissertations by Johnson (1970) and Waite (1971) is gratefully acknowledged. G. G. Connally, C. S. Denny, and B. C. McDonald reviewed early drafts of the manuscript. The work upon which this report is based was supported by funds provided by the United States Department of Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

WATER PLANES

General

Raised strandlines in the northern part of the Champlain Valley are marked by abundant but widely scattered shoreline features consisting primarily of deltas and beaches, but also including outlet channels, wave-cut benches, and spits. The locations of these features are shown in Figures 1 and 2. A listing of features, with pertinent information is provided in the appendix. Figure 3 is a north-south profile, constructed by westerly projection of features, with elevation control provided by contour lines from topographic maps.

Delineation of water planes is difficult in this area due to

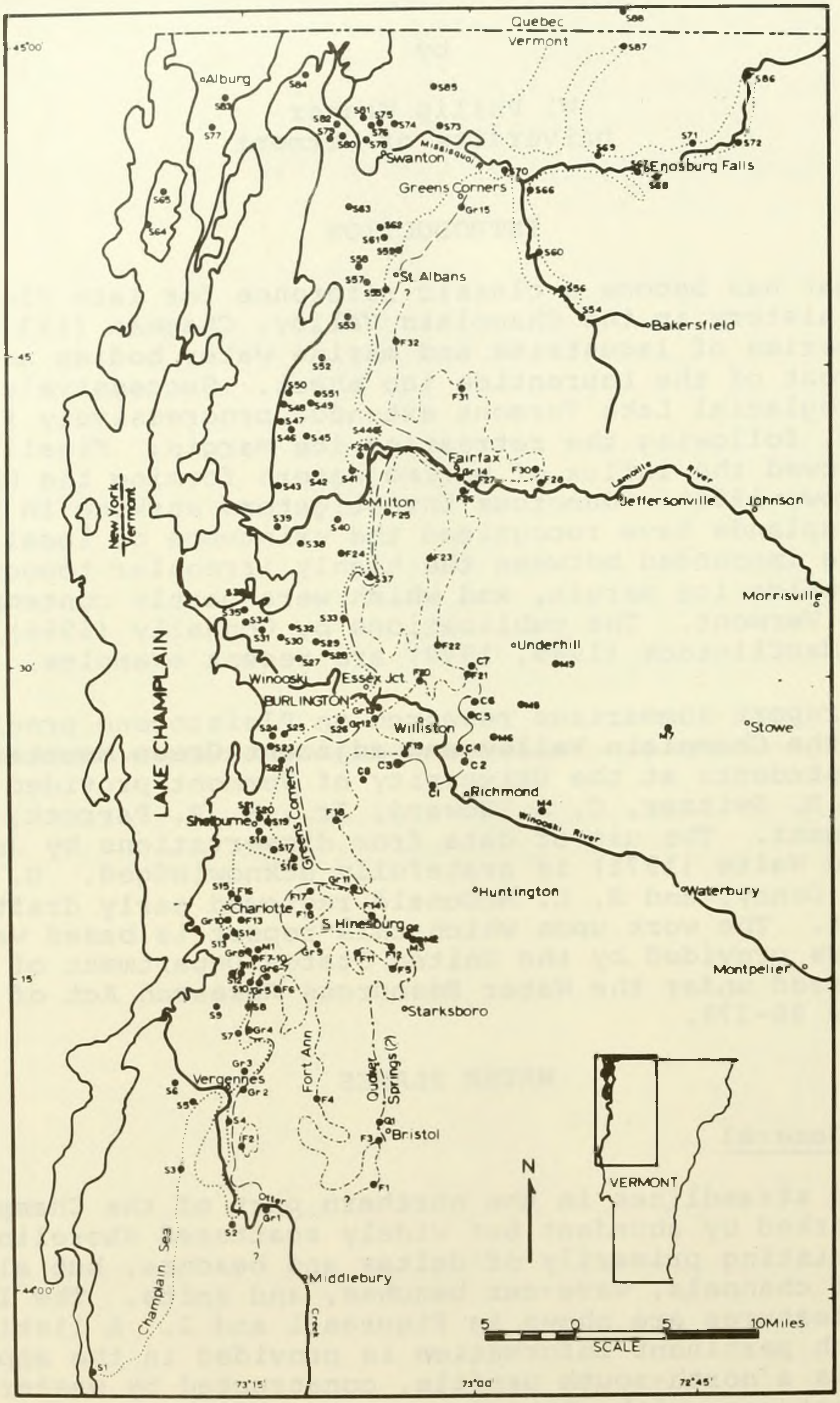

Figure 1: Shoreline feature locations and strandlines of regional water bodies in Champlain Valley: S = Champlain Sea; Gr = Greens Corners; F = Fort Ann; C = Coveville(?); Q = Quaker Springs(?); M = Miscellaneous.

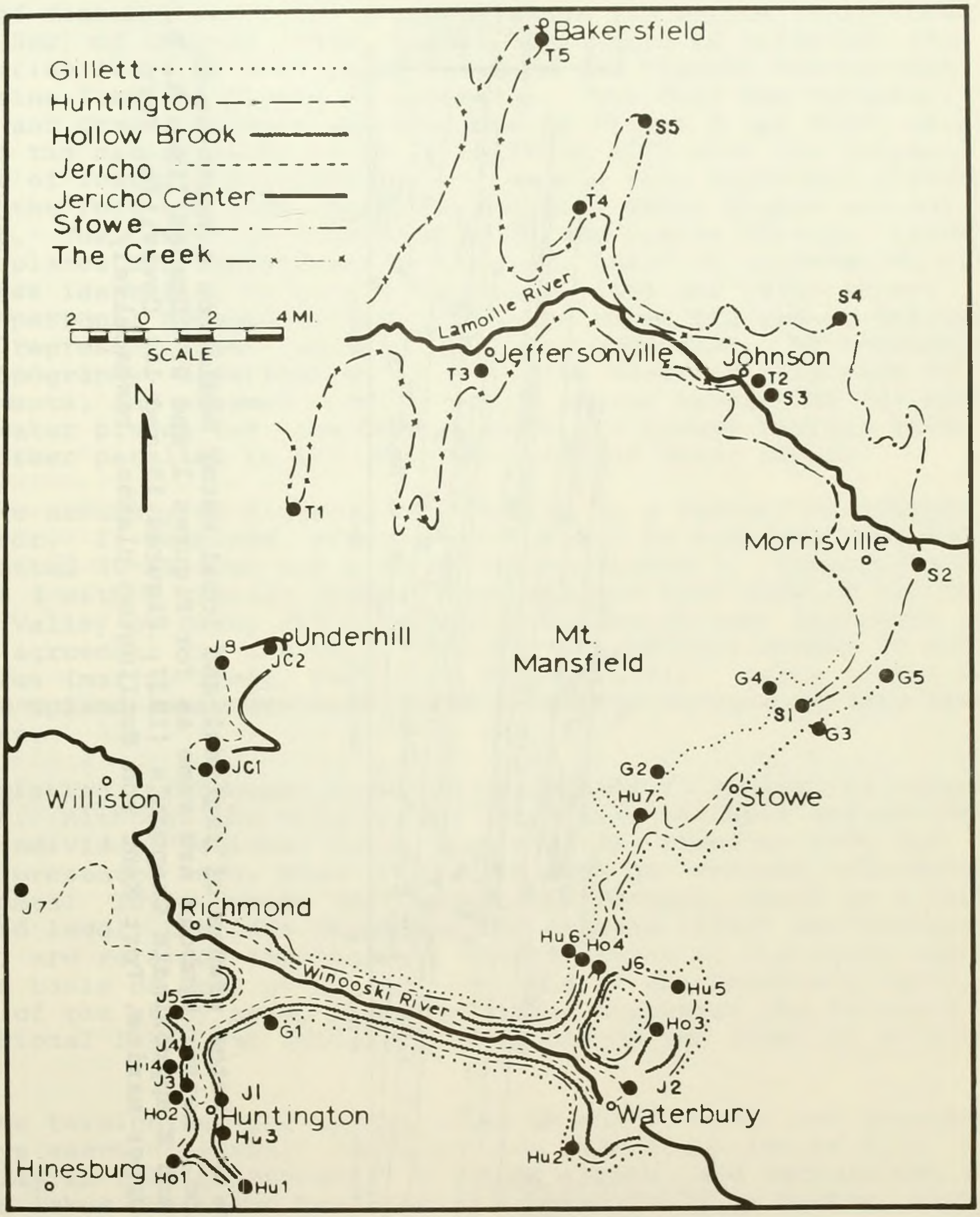

Figure 2: Shoreline feature locations and generalized strandlines of upland water bodies in the Green Mountains: G = Gillett; S = Stowe; T = The Creek; Hu = Huntington; Ho = Hollow Brook; J = Jericho; Jc = Jericho Center.

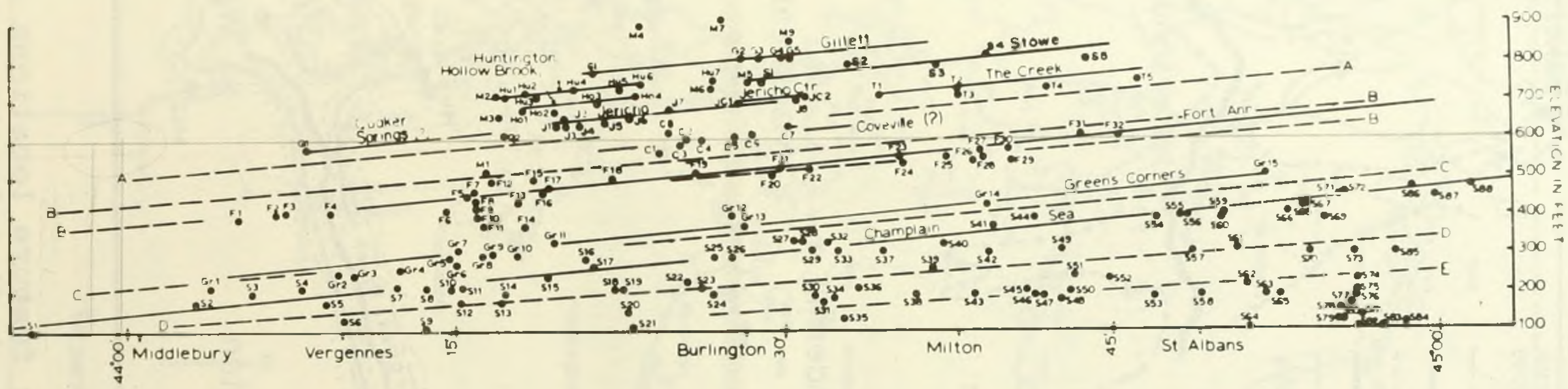

Figure 3: Water planes of regional and local water bodies on a north-south section. Letter symbols are same as for Figures 1 and 2. Dashed lines A, B, C, D and E approximate Chapman's (1937, Figures 15 and 16) Coveville, Fort Ann, upper marine, Port Kent and Burlington planes, respectively.

the large scatter of shoreline features. The most obvious alignment of features on Figure 3 approximates the marine limit (Champlain Sea) of Chapman (1937, Figure 16), which is different from the marine limit of this paper based on the highest occurrences of marine fossils (Figure 3; Appendix). The Fort Ann (Chapman, 1937) and Greens Corners water planes on Figure 3 are drawn parallel to the marine limit so as to coincide with both the largest number of features possible as well as the more prominent features. Above the Fort Ann level distinct regional water planes are not apparent. The Coveville (Chapman, 1937) and Quaker Springs (Stewart, 1961) planes are tentatively recognized, based on correlation with features identified by others (Connally, 1968 and 1970; Denny, 1970, personal communication). Features above the Quaker Springs level represent local lakes in the Green Mountains. By considering topography, distribution of shoreline features, drainage requirements, and assumed configurations of the Laurentide ice margin, water planes for local lakes above the Quaker Springs level were drawn parallel to the regional, lowland water planes.

The accuracy of Figure 3 is affected by a variety of sources of error. If combined, errors could result in some features being misplotted 40-50 feet too high or low on Figure 3. Comparison of Figure 3 with a similar profile from the New York side of the Champlain Valley by Denny (1970, personal communication) indicates very close agreement for the major regional strandlines common to both profiles (marine limit; Fort Ann; Coveville[?]). Water planes for local, upland lakes are considered tentative in view of data limitations.

Existing terminology has been considered in naming the various levels. Although the original or prevailing concepts associated with individual regional water planes differ somewhat from the views presented here, these differences do not warrant introducing new names. Thus, except for Lake Greens Corners, which is a newly defined level, the lake names used by Chapman (1937) and Stewart (1961) are retained for regional lake features in the study area. On the basis of work at the southern end of the Champlain basin, south of the study area, Connally (1968) suggested the renaming of regional lakes but this problem is beyond the scope of this report.

The terminology for upland lakes in the Winooski and Lamoille Valleys seems hopelessly confused (see literature review by G. G. Connally in this guidebook). For this reason, and because the upland lakes presented here differ substantially in number, extent, elevations, and drainage history from previous reports, new names are used in most cases. Where possible, geographic features near outlet channels associated with newly defined lakes are utilized for the new names. The only exception is Lake Jericho, which was previously named by Connally (1966).

Upland Lakes

Westward recession of the Laurentide ice margin uncovered successively lower outlets, resulting in progressive lowering of lake levels. Lakes Gillett, Huntington, Hollow Brook, Jericho Center, and Jericho developed in that order in the present Winooski drainage basin, and in the present Lamoille basin were Lakes Gillett, Stowe, and The Creek (Figure 2). Lake Gillett is the only lake that extended across the divide between the two present basins. The Lake The Creek outlet channel (T1, Figure 3) extends southward to a delta complex representing Lakes Jericho and Jericho Center (JC2 and J8, Figure 3) indicating general time-equivalence of these lakes. Similarly, the Lake Jericho outlet channel (J1, Figure 3) extends to the Coveville(?) level (C8, Figure 5) in the Champlain Valley, making it possible to relate the upland and regional lake histories.

In addition to the relationship between upland lakes and the Laurentide ice margin, Mountain glacial features can be correlated with the upland lakes, as was previously described (Wagner, 1970). In terms of the lake names used here, Mountain glacier ice margin positions in Ritterbush Valley and North Branch Lamoille River Valley may be contemporaneous with Lake Stowe.

Regional Lakes

The earliest regional lake in the Champlain Valley is represented by the Quaker Springs (?) plane on Figures 1 and 3. The northern extent of this lake probably terminated against the Laurentide ice margin south of Burlington. Slightly older and more southerly ice margin positions in late Quaker Springs (?) time can be inferred by drainage relations. The delta at Bristol (Q1, Figure 1) extends to an outwash surface heading in ice marginal glacial deposits south of Starksboro. The delta near South Hinesburg (Q2, Figure 1) indicates that the Laurentide ice sheet at that time blocked and diverted drainage in the Winooski River Valley through Hollow Brook Valley.

The Coveville (?) water plane (Figure 3) formed immediately after the Quaker Springs level (Stewart, 1961). Chapman's (1937, Figure 16) Coveville plane is shown on Figure 3. The Coveville (?) plane drawn here on Figure 3 is based primarily on features in the Winooski Valley. Although the plane is below Chapman's, it does agree with features identified as Coveville by Connally (1966, 1970) in Vermont and by Denny (1969, personal communication) in New York. The previously described Lake Jericho drainage relations indicate that the Laurentide ice margin blocked the Winooski Valley in Coveville (?) time. Subsequent ice retreat, still in Coveville (?) time, is required for development of Coveville (?) features in the Winooski Valley (Figure 3). Coveville (?) waters may have extended northward to the Lamoille Valley (Connally, 1966), and possibly into Quebec (Parrott and Stone, this guidebook).

The Fort Ann level, first described by Chapman (1937), is the highest regional water-body widely marked by numerous shoreline features on Figure 3. Chapman's (1937, Figures 15 and 16) Fort Ann planes in Vermont and New York, although not coincident, bracket the plane drawn here (Figure 3). The northern extent of the Fort Ann plane is uncertain. According to Chapman (1937, p. 112-113), and Parrott and Stone (this guidebook), the ice margin retreated north of the International Border in late Fort Ann time. McDonald (1968, p. 672-673) tentatively correlated strandline features in the Sherbrooke area of southeastern Quebec with the Fort Ann level. However, if the 230-foot elevation difference between the marine limit and Fort Ann strandlines in the Champlain Valley is compared with data in Quebec, then it appears that McDonald's features are about 25 feet too low to be an extension of the Fort Ann strandline from the Champlain Valley. As discussed below, it may be that Fort Ann time ended when Laurentide ice margin retreat exposed a low divide near Greens Corners, Vermont.

To the south, Fort Ann features, extend beyond the study area (Calkin, 1965; Connally, 1970). Like Chapman's profile, the Fort Ann plane on Figure 3 projects southward to the vicinity of the present Hudson - Champlain divide near Fort Edward, some eight miles south of and at least ten feet higher than Chapman's spillway at Fort Ann, New York.

Below the Fort Ann but above the upper Champlain Sea planes are shoreline features which can be represented by a previously unrecognized water plane (Figure 3). Southward extrapolation of this plane intersects the Champlain Valley floor below the divide, indicating drainage of the lake was northward. To the north the plane extends to a spillway near Greens Corners (Figures 1 and 3). The name "Lake New York" was previously applied (Wagner, 1969) for northward draining lake water immediately below the Fort Ann level and above the Champlain Sea limit, although no specific plane was recognized. Because no evidence for this plane has as yet been found in New York (Denny, 1970, personal communication), the name Greens Corners is applied rather than retain the name Lake New York.

Evidence for a late Pleistocene marine invasion of the St. Lawrence lowland has long been recognized and is generally referred to as the "Champlain Sea"(Karrow, 1961). In the Champlain Valley fossils (chiefly mollusks) and in northern parts "sensitive clay" indicate the presence of saline waters. Chapman (1937, Figure 16) delineated a strandline marking the marine limit, which, as shown on Figure 3, differs somewhat from the fossil-based Champlain Sea maximum of this paper. The only evidence, albeit inconclusive, to support the marine limit based on fossils is the parallelism of this and other water planes, plus close agreement with the marine limit in New York (Denny, 1970, personal communication). A shell date for locality S88(Appendix) basically agrees with the 12,000 year age suggested by McDonald (1968) for the marine maximum.

Below the marine limit Chapman recognized several marine water planes. Although the data on Figure 3 are inconclusive, there are alignments of features approximately coinciding with Chapman's (1937, Figure 16) Port Kent and Burlington levels. In the Winooski Valley deltas are clustered at both the marine limit and at a somewhat lower level (Figure 3) with a pronounced scarp intervening, supporting the Port Kent level (Johnson, 1970). The Port Kent as a level is also supported by shell dates of about 11,300 yrs. B.P. from localities S14 and S24, although there is a discrepancy between shell and wood dates at locality S24 (Appendix). Similarly, age dates from two marine shell localities (nos. S48 and S65) may document the Burlington level as a time line. In Quebec, McDonald (1968, p. 673) found marine shore features were best developed at 115-140 feet below the upper limit, which approximately coincides with Chapman's Port Kent level. However, in northern New York, on the west side of the Champlain Valley, Denny (1969, personal communication) has mapped numerous Champlain Sea features with no apparent stillstand below the marine limit. Recent work with sediments submerged in modern Lake Champlain indicates the end of the Champlain Sea may have occurred about 10,200 years ago (Chase, 1972).

SPECULATIONS

The early work of Chapman established a framework for the late Pleistocene history in northwestern Vermont. This framework is fundamental and likely will stand with little modification. Radiocarbon dates, although only from the Champlain Sea deposits in this area, tend to support Chapman's views. For events preceding and leading up to the Champlain Sea, there is some evidence that the succession of water bodies may not be as straightforward as generally believed. First, some of the deltas at the marine limit in the Missisquoi Valley, and to a lesser extent elsewhere, have complete or nearly complete surface and near-surface veneers of bottom-set sediment (S16; S26; S66; S68; S88). Some other deltas at the marine limit have unusual thicknesses of topset sediment. Secondly, at least two of the marine limit deltas in the Missisquoi Valley have included bodies of till. Thirdly, in the northwestern part of the area are numerous exposures of till overlying a variety of sediments. Figure 4 is a speculative time-space diagram constructed to account for these aspects. As shown, ice recession was accompanied by successive lowering of water levels in the classical fashion, in other words, Quaker Springs, Coveville, Fort Ann, and Champlain Sea. Next, a minor oscillation of the ice margin temporarily reestablished a higher freshwater level, possibly the Fort Ann. At this time some of the previously formed Champlain Sea deltas were submerged and partly veneered with bottom-set sediment and till.

Subsequent recession then lowered the water level to form Lake Greens Corners in the Champlain Valley south of the spillway at

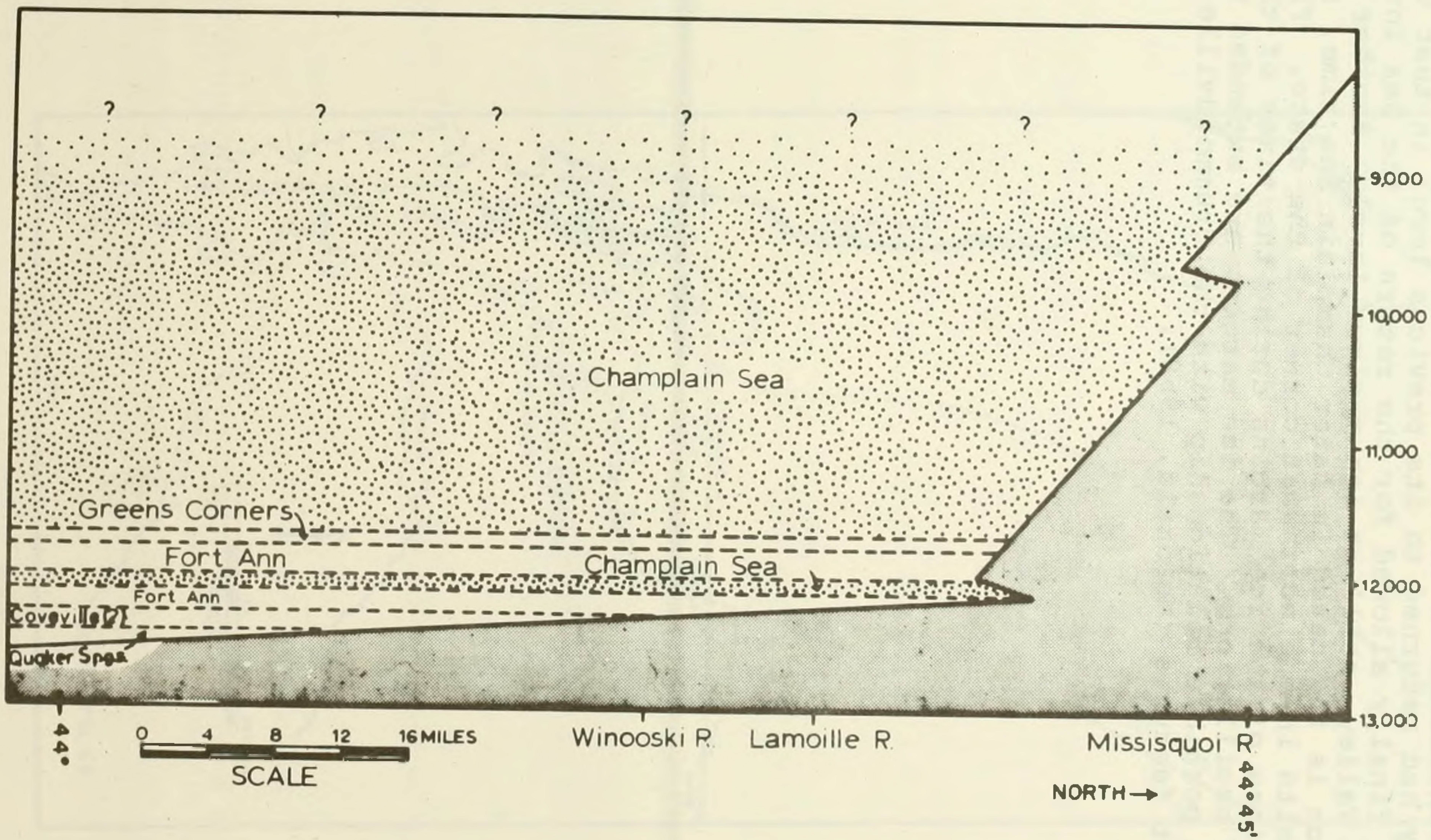

Figure 4: Glacier (shaded) and water body (stippled and plain) relationships in time and space, drawn along 73°10' west longitude meridians.

Greens Corners. Because this spillway extends to a normal delta at the marine limit in the Missisquoi Valley, the Sea by this time apparently had returned to its previous level in that valley. Ice recession finally allowed for the return of the Sea into all of the Champlain Valley, still at its maximum level. Another ice margin oscillation is indicated in later Champlain Sea time, resulting in till deposits in the northwest corner of the state. Figure 5 shows the positions of the ice margins during the times of the positive, southward oscillations. The ice margins are extended into Quebec to show a possible relationship with the Drummondville and Highland Front features (McDonald, 1968).

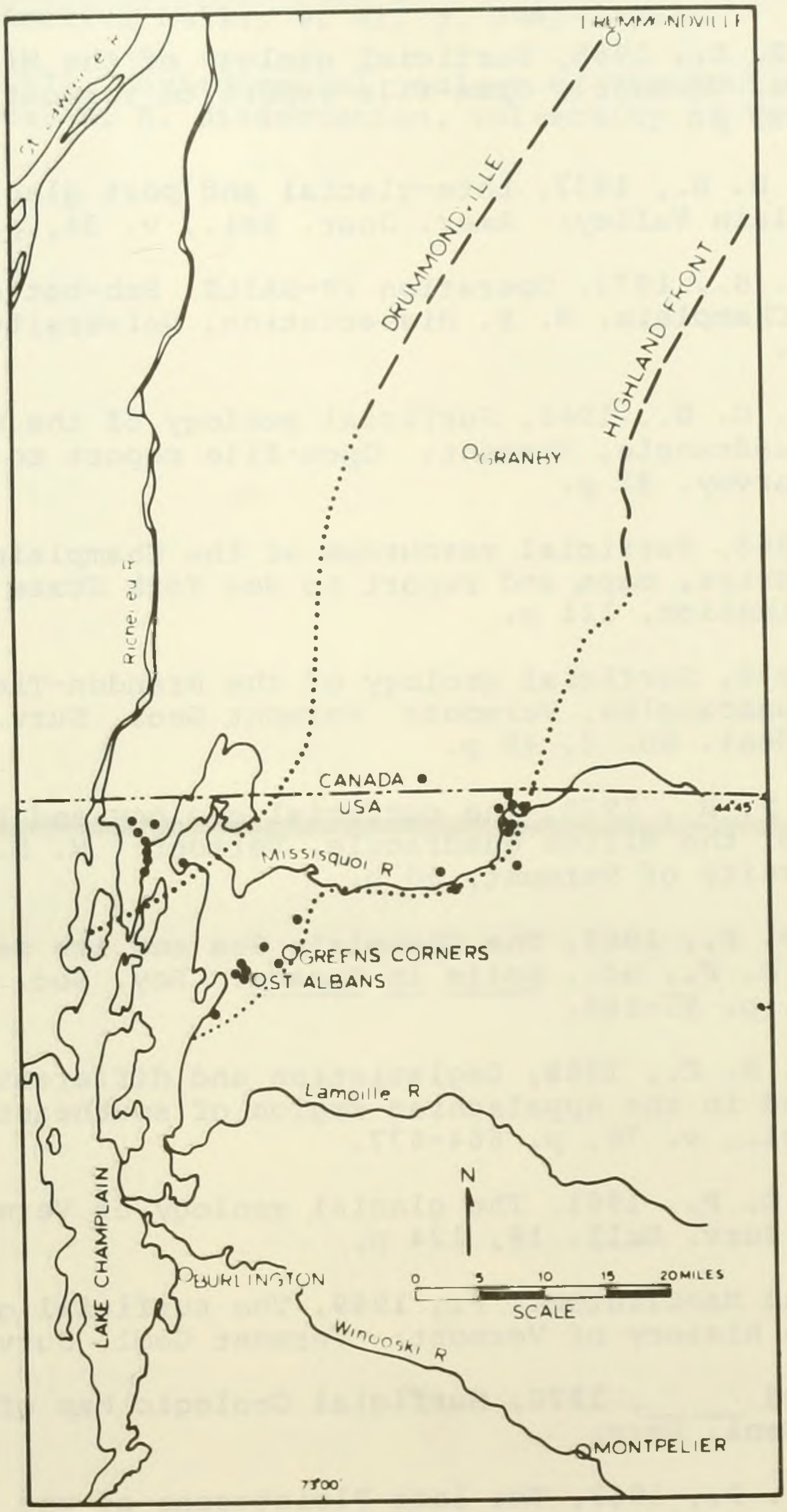

Figure 5; Ice margins in Champlain Valley (dotted lines), and Quebec (dashed lines; from McDonald, 1969, personal communication); Filled circles represent exposures of till overlying non-glacial sediment.

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APPENDIX: Location and Description of Shoreline Features

Feature Name and Number		Type of Feature	Elevation (feet)	Location and Miscellaneous
Gillett	1	outlet channel	760-780	7.5 miles northeast of Gillett Pond; Hunting-ton quad.
	2	delta	800-820	1.5 miles west of Stowe; West Waterbury R.; Mont-pelier quad.
	3	delta	800-820	3.3 miles northeast of Stowe; Glen Bk.; Montpel-ier quad.
	4	delta	820-840	9 miles south of Johnson; Sterling Bk.; Hyde Park quad.
	5	delta	800-820	3.4 miles south of Morris-ville; Bedell Bk.; Hyde Park quad.
Stowe	1	divide	740-760	3.1 miles northeast of Stowe; Montpelier quad.
	2	delta	780-800	Morrisville; Lamoille R.; Hyde Park quad.
	3	delta	780-800	0.8 mile southeast of Johnson; Lamoille R.; Hyde Park quad.
	4	delta	800-840	3 miles northeast of John-son; Gihon R.; Hyde Park quad.
	5	delta	800-820	Belvidere Jct.; North Br., Lamoille R.; Hyde Park quad
The Creek	1	outlet channel	700-720	0.6 mile south of North Underhill; Underhill quad.
	2	delta	720-740	Johnson; Lamoille R.; Hyde Park quad.
	3	delta	700-720	0.7 mile south of Jeffer-sonville; Brewster R.; Jeffersonville quad.
	4	delta	720-740	0.6 mile north of Water-ville; North Br. Lamoille R.; Jeffersonville quad.
	5	delta	740-760	Bakersfield; The Branch; Enosburg Falls quad.
Hunt-ington	1	delta	700-720	Huntington Ctr.; Brush Bk.; Huntington quad.
	2	delta	700-740	1.7 miles southwest of Waterbury; Crossett Br.; Waterbury quad.

Feature Name and Number		Type of Feature	Elevation (feet)	Location and Miscellaneous
Hunt-ington	3	delta	700-720	0.6 mile southeast of Huntington; unnamed stream; Huntington quad.
	4	delta	740-760	1.3 miles northwest of Huntington; unnamed stream; Huntington quad.
	5	delta	720-740	Waterbury Ctr.; Thatcher Bk.; Montpelier quad.
	6	delta	720-740	3.8 miles northwest of Waterbury; Stevenson Br.; Bolton Mtn. quad.
	7	delta	700-760	1.3 miles northwest of Moscow; Miller Bk.; Montpelier quad.
Hollow Brook	1	outlet channel	660-680	3 miles northeast of S. Hinesburg; Hinesburg quad.
	2	delta	660-680	4.5 miles northeast of S. Hinesburg; unnamed stream; Hinesburg quad.
	3	delta	680-700	1.3 miles south of Waterbury Ctr.; Thatcher Br.; Montpelier quad.
	4	delta	700-720	3.8 miles northwest of Waterbury; Stevenson Br.; Bolton Mtn. quad.
Jericho	1	delta	620-640	Huntington; Huntington R.; Huntington quad.
	2	delta	640-660	Waterbury; Winooski R.; Montpelier quad.
	3	delta	620-640	1.2 miles northwest of Huntington; unnamed stream; Huntington quad.
	4	delta	620-640	1.5 miles northwest of Huntington; unnamed stream; Huntington quad.
	5	delta	620-640	2.8 miles northwest of Huntington; unnamed stream; Huntington quad.
	6	delta	640-660	3.8 miles northwest of Waterbury; Stevenson Bk.; Bolton Mtn. quad.
	7	outlet channel	660-680	1.9 miles southwest of Williston; Essex Jct.quad.
	8	delta	690	1 mile northeast of Jericho; Browns R.; Underhill quad.

Feature Name and Number	Type of Feature	Elevation (feet)	Location and Miscellaneous
Jericho Center 1	outlet channel	680-700	Jericho Center; Richmond quad.
2	delta	706	Underhill; Browns R. and The Creek; Underhill quad.
Quaker Springs (?) 1	delta	560-580	Bristol; New Haven R.; Bristol quad.
2	delta	600-620	0.4 mile southeast of S. Hinesburg; Hollow Brook; Hinesburg quad.
Cove- ville (?) 1	delta	540-580	1.5 miles northwest of Richmond; Winooski R.; Essex Jct. quad.
2	delta	580-600	1.5 miles north of Rich- mond; Mill Bk.; Richmond quad.
3	delta	560-600	0.4 mile south of Willis- ton; Allen Bk.; Essex Jct. quad.
4	delta	580-600	2.6 miles northwest of Richmond; Winooski R.; Essex Jct. quad.
5	delta	606	0.9 mile southwest of Jericho Center; unnamed brk.; Richmond quad.
6	delta	600-620	1.6 miles southeast of Jericho; Lee R.; Rich- mond quad.
7	delta	620-640	at Jericho; Browns R.; Underhill quad.
8	delta	600-620	
Fort Ann 1	delta(?)	380-400	0.9 mile east of New Hav- en Mills; unnamed stream; South Mtn. quad.
2	beach	390-400	2.3 miles southeast of Vergennes; west side of Buck Mtn.; Monkton quad.
3	delta	400-420	0.6 mile south of Bris- tol; New Haven R.; Bris- tol quad.
4	spit	400-410	4.1 miles northwest of Bristol; Monkton quad.
5	delta	420-480	0.8 mile east and north- east of Hogback Mtn.; Hinesburg quad.
6	beach	400-420	1.5 miles east of N. Ferrisburg; Mt. Philo quad.
7	beach	440-460	southwest side of Mt. Philo; Mt. Philo quad.

Feature Name and Number	Type of Feature	Elevation (feet)	Location and Miscellaneous
Fort Ann 8	beach	420-440	southwest side of Mt. Philo; Mt. Philo quad.
9	beach	400-420	southwest side of Mt. Philo; Mt. Philo quad.
10	beach	360-380	southwest side of Mt. Philo; Mt. Philo quad.
11	delta	380-400	1.9 miles southwest of S. Hinesburg; Lewis Creek; Hinesburg quad.
12	delta	460-500	South Hinesburg; Hollow Brook; Hinesburg quad.
13	beach	400-460	south side of Pease Mountain; Mt. Philo quad.
14	delta	360-380	1.9 miles southeast of Hinesburg; LaPlatte R.; Hinesburg quad.
15	beach	480-500	four unnamed hillocks about 1.3 miles east of E. Charlotte; Mt. Philo quad.
16	beach	440-460	south side of Jones Hill; Mt. Philo quad.
17	beach	440-500	0.8 mile northeast of East Charlotte; Mt. Philo quad.
18	bench	480-510	0.2 mile north of Rts. 116 and 2A, intersection and north along Rt. 116; Mt. Philo and Burlington quads.
19	delta	500-520	Williston; Winooski R.; Essex Jct. quad.
20	delta	480-520	1.1 miles east of Essex Jct.; Winooski River; Essex Jct. quad.
21	delta	500-540	0.2 mile south of Jericho Cemetery; Lee R.; Underhill quad.
22	delta	500-525	Essex Center; Alder Brook; Essex Center quad.
23	delta	530-550	Brookside Cemetery; Rogers Brook; Essex Center quad.
24	beach	520-540	southeast side of Cobble Hill; Fort Ethan Allen quad.
25	beach	520-580	1.3 miles west of Milton Pond; Milton quad.
26	delta	520-540	2.5 miles north of Westford; Browns River; Gilson Mtn. quad.

Feature Name and Number		Type of Feature	Elevation (feet)	Location and Miscellaneous
Fort Ann	27	delta	540-580	Fairfax Falls; Lamoille R.; Gilson Mtn. quad.
	28	delta	540-560	River View School; Lamoille R.; Gilson Mtn. quad.
	29	beach	520-560	east side of Arrowhead Mtn.; Milton quad.
	30	delta	560-580	Binghamville; Stones Brook; Gilson Mtn. quad.
	31	delta	600-620	Buck Hollow; esker-fed; Milton quad.
	32	beach	590-610	0.7 mile southwest of Bellevue Hill; St. Albans quad.
Greens Corners	1	delta	200-220	Weybridge; Otter Creek; Middlebury quad.
	2	beach	240-250	0.8 mile southeast of Vergennes; Monkton quad.
	3	beach	230-250	0.8 mile northeast of Vergennes; Monkton quad.
	4	beach	260	0.8 mile northeast of Ferrisburg; Monkton quad.
	5	delta	280-300	0.5 mile southwest of North Ferrisburg; Lewis Creek; Mt. Philo quad.
	6	beach	260-280	0.1 mile northwest of Coleman Corner; Mt. Philo quad.
	7	beach	300-320	0.2 mile north of Coleman Corner; Mt. Philo quad.
	8	beach	280-300	0.9 mile west of Mt. Philo; Mt. Philo quad.
	9	delta(?)	300	1 mile south of Prindle Corners; Lewis Creek; Mt. Philo quad.
	10	beach	280-300	0.3 mile southeast of Barber Hill; Willsboro quad.
	11	delta(?)	320-340	0.4 mile northwest of Hinesburg; LaPlatte R.; Hinesburg quad.
	12	beach	380-400	1.9 miles southeast of Essex Jct.; Essex Jct. quad.
	13	delta	360-380	1.4 miles southeast of Essex Jct.; Winooski R.
	14	delta	420-440	Fairfax; Lamoille R.; Milton quad.
	15	delta & outlet channel	500-510	1.5 miles northeast of Greens Corners; St. Albans quad.

Feature Name and Number	Type of Feature	Elevation (feet)	Location and Miscellaneous
Champlain Sea 1	delta	100	1.5 miles south of West Bridport; Crown Pt. quad.mollusks; 9,620 ± 350 B.P. shell date I-4695.
2	delta	175	1.3 miles southwest of Weybridge; Middlebury quad.
3	beach	180-200	3 miles north of Addison; Port Henry quad.
4	beach	200-210	≈.7 mile northwest of Buck Mt.; Monkton quad.
5	delta	160-180	1.6 miles west of Vergennes; Port Henry quad.
6	delta	120-140	2 miles northeast of Panton; Port Henry quad.
7	beach	200-210	.2 mile northeast of Ferrisburg; Monkton quad.
8	beach	200-210	1.9 miles northeast of Ferrisburg; Monkton quad.
9	delta	100-120	≈1 mile east of Hawkins Bay; Port Henry quad.
10	delta	200-220	1.2 miles southwest of North Ferrisburg; Mt. Philo quad.
11	beach	200-220	1.9 miles northwest of North Ferrisburg; Mt. Philo quad.
12	delta	160-180	1.5 miles west of North Ferrisburg; Mt. Philo quad.
13	beach	160-180	2.5 miles south of Charlotte; Willsboro quad.; mollusks.
14	beach	180-200	1.8 miles southeast of Charlotte and west of Thompsons Point; Willsboro quad.; mollusks; 11,230±170 B.P. shell date I-3647.
15	beach	240-260	.6 mile southwest of Jones Hill cemetery; Mt. Philo quad.
16	delta	260-300	1.9 miles southeast of Shelburne Falls; Mt. Philo quad.
17	delta	260-280	.9 mile south of Shelburne Falls; Mt. Philo quad.

Feature Name and Number	Type of Feature	Elevation (feet)	Location and Miscellaneous
Champlain Sea 18	delta	200-220	.3 mile west of Shelburne Falls; Mt. Philo quad.
19	beach	200-220	1.8 miles east of Shelburne; Burlington quad.; mollusks.
20	delta	140-160	.3 mile northeast of Shelburne; Burlington quad.
21	delta	100-120	1.5 miles northwest of Shelburne; Burlington quad.
22	beach	140-300	.7 mile southeast of Twin Orchards; Burlington quad.
23	beach	200-270	.5 mile southeast of Queen City Park; Burlington quad.
24	beach	180-200	1.8 miles northeast of Queen City Park; Burlington quad.; mollusks and wood; 10,950±300 B.P. wood date W-2309; 11,420 ±350 shell date W-2311.
25	beach	280-300	1.5 miles southwest of South Burlington; Burlington quad.
26	delta	280-300	2 miles southeast of South Burlington on Rte. 2; Burlington quad.
27	delta	320-340	.3 mile west of Ft. Ethan Allen Military Res.; Ft. Ethan Allen quad.
28	delta	320-340	1.1 miles northwest of Ft. Ethan Allen; Ethan Allen quad.
29	delta	300-320	1.5 miles northwest of Ft. Ethan Allen; Ethan Allen quad.
30	delta	180-200	.4 mile east of Shipman Hill; Ft. Ethan Allen quad.
31	delta	160-180	.4 mile southwest of Bayside; Ft. Ethan Allen quad.
32	beach	320-340	1.5 miles southwest of Colchester; Ft. Ethan Allen quad.

Feature Name and Number	Type of Feature	Elevation (feet)	Location and Miscellaneous
Champlain Sea 33	delta	300-320	1.4 miles east of Colchester; Ft. Ethan Allen quad.
34	beach	170-190	1.2 miles west of Bayside; Ft. Ethan Allen quad; mollusks.
35	delta	120-140	1.2 miles from tip of Malletts Head; Ft. Ethan Allen quad.
36	beach	200-220	.8 mile from tip of Malletts Head; Ft. Ethan Allen quad.
37	delta	300-320	1.4 miles north of Colchester Pond; Essex Center quad.
38	delta	190-200	.8 mile northwest of Chimney Corner; Ft. Ethan Allen quad.
39	beach	250-270	.9 mile northwest of Walnut Ledge; Ft. Ethan Allen quad. mollusks.
40	delta	320-340	at Checkerberry Village; Georgia Plains; mollusks; 10,520±180 B.P. shell date I-4393.
41	delta	360-380	.8 mile south of Arrowhead Mtn.; Milton quad.
42	delta	300-320	.7 mile south of Towns Corner School; Georgia Plains quad.
43	beach	180-200	.6 mile southwest of Silvertown School; Georgia Plains quad.
44	delta	380-400	.4 mile north of Arrowhead Mountain Lake; Milton quad.
45	delta	200-220	.7 mile east of Miltonboro; Georgia Plains quad.
46	delta	180-200	.1 mile north of Miltonboro; Georgia Plains quad.
47	beach	170-190	.6 mile northwest of Miltonboro; Georgia Plains quad.; mollusks.
48	beach	160-200	1.2 miles northwest of Miltonboro; Georgia Plains quad.; mollusks; 10,460±180 B.P.; shell date I-4394.

Feature Name and Number	Type of Feature	Elevation (feet)	Location and Miscellaneous
Champlain Sea 49	beach	300-320	2.5 miles southeast of Georgia Plains; Georgia Plains quad.; mollusks.
50	beach	190-220	1.5 miles west of Georgia Plains; Georgia Plains quad.; mollusks.
51	delta	240-260	at Georgia Plains; Georgia Plains quad.
52	delta	230-240	.6 mile southeast of Melville Landing; St. Albans Bay quad.
53	delta	180-200	1 mile northeast of Lime Rock Pt.; St. Albans Bay quad.
54	delta	380-400	at East Fairfield; Enosburg Falls quad.
55	beach	380-400	.6 mile west of Holy Cross Cemetery; St. Albans quad.
56	delta	380-400	2.5 miles northwest of East Fairfield; Enosburg Falls quad.
57	beach	300-320	1 mile west of Holy Cross Cemetery; St. Albans quad.
58	beach	180-200	2 miles northwest of St. Albans; St. Albans quad.
59	beach	390-400	.1 mile east of WWSR radio tower; St. Albans quad.
60	delta	380-400	.5 mile north of Fairfield Station; Enosburg Falls quad.
61	beach	310-320	1.5 miles south of Fonda; St. Albans quad.
62	beach	220-230	.7 mile south of Fonda; St. Albans quad.
63	beach	180-200	at gravel pit Morin Road south of Swanton; East Alburg quad.
64	beach(?)	100-120	1.5 miles southeast of Town of Isle La Motte; Rouses Point quad.;mollusks.
65	beach(?)	180-200	.7 mile north of Town of Isle La Motte; Rouses Point quad.; mollusks.
66	delta	400-420	at Sheldon; Enosburg Falls quad.
67	delta	420-440	at Enosburg Falls; Enosburg Falls quad.

Feature Name and Number	Type of Feature	Elevation (feet)	Location and Miscellaneous
Champlain Sea 68	delta	420-440	.5 mile south of Enosburg Falls; Enosburg Falls quad.
69	delta	380-400	at South Franklin; Enosburg Falls quad.
70	delta	300-320	1 mile west of Sheldon Springs; Enosburg Falls quad.
71	delta	440-460	Enosburg Falls; Enosburg Falls quad.
72	delta	440-460	at East Berkshire; Jay Peak quad.
73	delta	300-310	1.1 miles east of Highgate Ctr.; Highgate Ctr. quad.
74	delta	230-250	1.5 miles east of Swanton; Highgate Ctr. quad.
75	beach	200-210	.9 mile east of Swanton; Highgate Ctr. quad.
76	beach	189	.6 mile east of Swanton; Highgate Ctr. quad.
77	beach	160-180	1.5 miles west of Bluff Point; Rouses Point quad.
78	delta	150-160	at Swanton; Highgate Ctr. quad.
79	beach	120-130	1.3 miles west of Swanton; East Alburg quad.
80	delta	120-140	.4 mile north of Swanton; East Alburg quad.
81	beach	140	1.1 miles north of Swanton; Highgate Ctr. quad.
82	delta	100-120	1.4 miles northwest of Swanton; East Alburg quad.
83	delta	100-120	.5 mile west of Blue Rock; Rouses Point quad.,mollusks(?)
84	beach	120-130	1.2 miles northeast of West Swanton, East Alburg quad.; mollusks.
85	beach	300	1.3 miles southwest of Center Pond; Highgate Ctr. quad.; mollusks.
86	delta	460-480	.9 mile southwest of Richford; Jay Peak quad.
87	delta	440-460	.25 mile north of North Enosburg; Enosburg Falls quad.
88	delta	475	2 miles south of Frelighsburg, Quebec; mollusks; 11,740±200 B.P. shell date I-4489.

Feature Name and Number	Type of Feature	Elevation (feet)	Location and Miscellaneous
Miscellaneous			
1	spit?	500-520	Mount Philo; Mt. Philo quad.
2	kame-delta	700-720	1.1 miles east of South Hinesburg; Hinesburg quad.
3	delta	640-660	.7 mile east of South Hinesburg; Hinesburg quad.
4	kame-delta	880-900	1.3 miles northeast of Jonesville; Richmond quad.
5	kame-delta	740-760	1 mile west of Oak Hill School; Essex Jct. quad.
6	kame-delta	720-740	1.1 miles south of Jericho Ctr.; Richmond quad.
7	kame-delta	900-920	2.3 miles east of Lake Mansfield; Bolton quad.

PROGLACIAL LAKES IN THE LAMOILLE VALLEY, VERMONT

by

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Three proglacial lakes were present in the Lamoille Valley during, and following, retreat of the late Woodfordian glacier in the Champlain Valley. This glacier deposited the Burlington drift of Stewart and MacClintock (1969). Although these lake levels have been recognized since the early part of this century, the nomenclature is still confused, as seen in Table 1. This discussion is a summary of previously published works of others, and of field work performed sporadically for the past six years. Because the names Lake Lamoille and Lake Mansfield have priority in the Lamoille Valley, they are retained in this paper.

TABLE 1.

MERWIN, 1908	CHAPMAN, 1937 1942	STEWART, 1961
Lake Lamoille I	---	Lake Mansfield
Lake Mansfield	---	Lake Lamoille
Lake Lamoille III	Coveville Stage (Lake Vermont)	Coveville Stage (Lake Vermont)

CONNALLY, 1966 1968	STEWART AND MACCLINTOCK, 1969	CONNALLY, 1971
Lake Lamoille	Quaker Springs Stage ? (Lake Vermont)	Lake Lamoille
Lake Mansfield	Quaker Springs Stage ? (Lake Vermont)	Lake Mansfield
Coveville Stage (Lake Vermont)	Coveville Stage (Lake Vermont)	Lake Coveville

Merwin (1908) recognized an upper level (above 800'), designated Lake Lamoille I, that he thought had been restricted to the Lamoille Valley. He proposed that the lowland east of Mount Mansfield, between Morrisville and Stowe, was then cut down by steadily lowering lake waters, designated Lake Lamoille II. Then, when the outlet was breached to its present level (740') the waters of Lake Lamoille II and Lake Winooski I, in the Winooski Valley to the south, joined to form Lake Mansfield. The lowest level in the Lamoille Valley (650'), presumed to have been restricted to that valley, was named Lake Lamoille III. Fairchild (1916) recognized Merwin's terminology in the Lamoille Valley except that he erroneously projected his upper marine limit (the Champlain Sea) in place of Lake Lamoille III. Chapman (1937, 1942) projected the Coveville Stage of Lake Vermont to Merwin's Lake Lamoille II features, an interpretation that has been generally recognized to the present, the only change being the redesignation as Glacial Lake Coveville by Connally and Sirkin (1970). In mapping the bedrock geology of the Mount Mansfield quadrangle Christman (1959, p. 73) clearly recognized the priority of Merwin's terms although he chose "Lake Lamoille deposits"(quotations his) as a mapping unit.

Stewart (1961) correctly inferred that the upper lake actually extended into the Winooski Valley and was not restricted to the Lamoille Valley as Merwin (1908, p. 132) had supposed. He also inferred that the lower lake did not - an interpretation supported here - also contrary to the concepts of Merwin (ibid, p. 136). Stewart therefore honored the conceptual priority and renamed the upper lake, Lake Mansfield, and the lower, Lake Lamoille, reversing Merwin's terms. Connally (1966, 1968), however, re-established Merwin's names, concluding that the original elevations and features were the most important precedent. Then, Stewart and MacClintock (1969) thoroughly confused matters by reapplying the names Lake Lamoille and Lake Mansfield to problematical higher levels and by apparently assigning both of Merwin's levels to the Quaker Springs Stage of Lake Vermont, even though these lakes are not at the proper elevations (Connally, 1966, 1968, and elsewhere) for the Champlain Valley lake.

Merwin's original terminology is retained and defended here for three reasons: (1) these terms were accepted for more than 50 years prior to the work of Stewart, (2) these terms were applied to specific features and elevations that have been studied and restudied for more than 60 years, and (3) it is less confusing to either extend (Lake Lamoille) or restrict (Lake Mansfield) existing terms, when they are meaningful, than to introduce new names because of original conceptual flaws.

GLACIAL LAKE LAMOILLE

This lake is defined by six deltas in the Lamoille Valley and at least four between Morrisville and Stowe, east of Mount

Mansfield. Two of the deltas near Stowe were originally mapped by Wagner (1970, personal communication). The Lake Lamoille deltas (Figure 1) range from 840' in the northwest to 780' in the southeast, as determined from flat delta tops depicted on 7 1/2' topographic maps. Lake Lamoille was blocked by the ice margin in the west and drained southward via the Winooski Valley. Wagner has located the outlet for this lake at about 760' at Gillett at the west end of the Winooski Valley. Figure 2 shows a projection of Lakes Lamoille, Mansfield, and Coveville along A-A' in Figure 1.

GLACIAL LAKE MANSFIELD

This lake is defined by seven deltas and two beaches. The deltas (Figure 3) range from 760' in the north to 720' in the south. Merwin suggested that this lake coalesced with one in the Winooski Valley, however, the divide may be about 20' too high to have permitted this (Figure 2). I suggest that initial drainage was through the Stowe lowland, while the ice blocked the valley of The Creek west of Mount Mansfield. Later, the ice block was dissected in The Creek and this channel controlled falling lake levels. The The Creek channel is at 700' and no shoreline features are graded to this elevation so it must have controlled a very short-lived lake level. Since Lake Mansfield is now defined only in the Lamoille Valley, this restricts the original definition of Merwin (1908).

GLACIAL LAKE COVEVILLE

This lake is documented by nine deltas and two beaches (Figure 4) that range from 660' to 640' at Morrisville. The inclusion of these features with Lake Coveville has never been challenged but it is fraught with problems as discussed by Wagner (1969). Connally and Calkin (1972) document the retreat of an active ice margin during Lake Coveville, including the Bridport readvance that took place between Burlington and Bridport(south of Middlebury). The retreating margin of an active glacier may account for many of the problems outlined by Wagner. A projection of Lamoille Valley features onto a generalized north-south Lake Coveville projection in the Champlain Valley strongly supports coincidence of the levels (Figure 5).

TIME STRATIGRAPHY

In Figure 5 a hypothetical projection of Lake Quaker Springs is shown. Both Lake Lamoille and Lake Mansfield had to drain southward into the Champlain Valley. If the projections are correct, Lake Mansfield must have drained into Lake Coveville (via Lake Jericho in the Winooski Valley) and not Lake Quaker Springs. Perhaps

Lake Mansfield was dammed by the Bridport readvance after a period of free drainage. Differential rebound (Figure 2) between Lake Lamoille and Lake Mansfield suggests that some event separated the two lakes and that Lake Lamoille drained through a series of impondments into Lake Quaker Springs at its northern boundary near Brandon.

Connally and Sirkin (1972) have estimated the age of Lake Coveville as 12,800 yrs. B.P. and the Luzerne readvance, that they tentatively correlated with the Burlington drift, as 13,200 yrs. B.P. Thus, it is probable that Lakes Lamoille and Mansfield existed sometime between 13,200 and 12,800 yrs. B.P. Because two of the local mountain glaciers reported by Wagner (1970) can be directly related to Lake Lamoille; one in the Ritterbush Valley and one east of Belvidere Center, it is probable that these glaciers also existed between 13,200 and 12,800 yrs. B.P.

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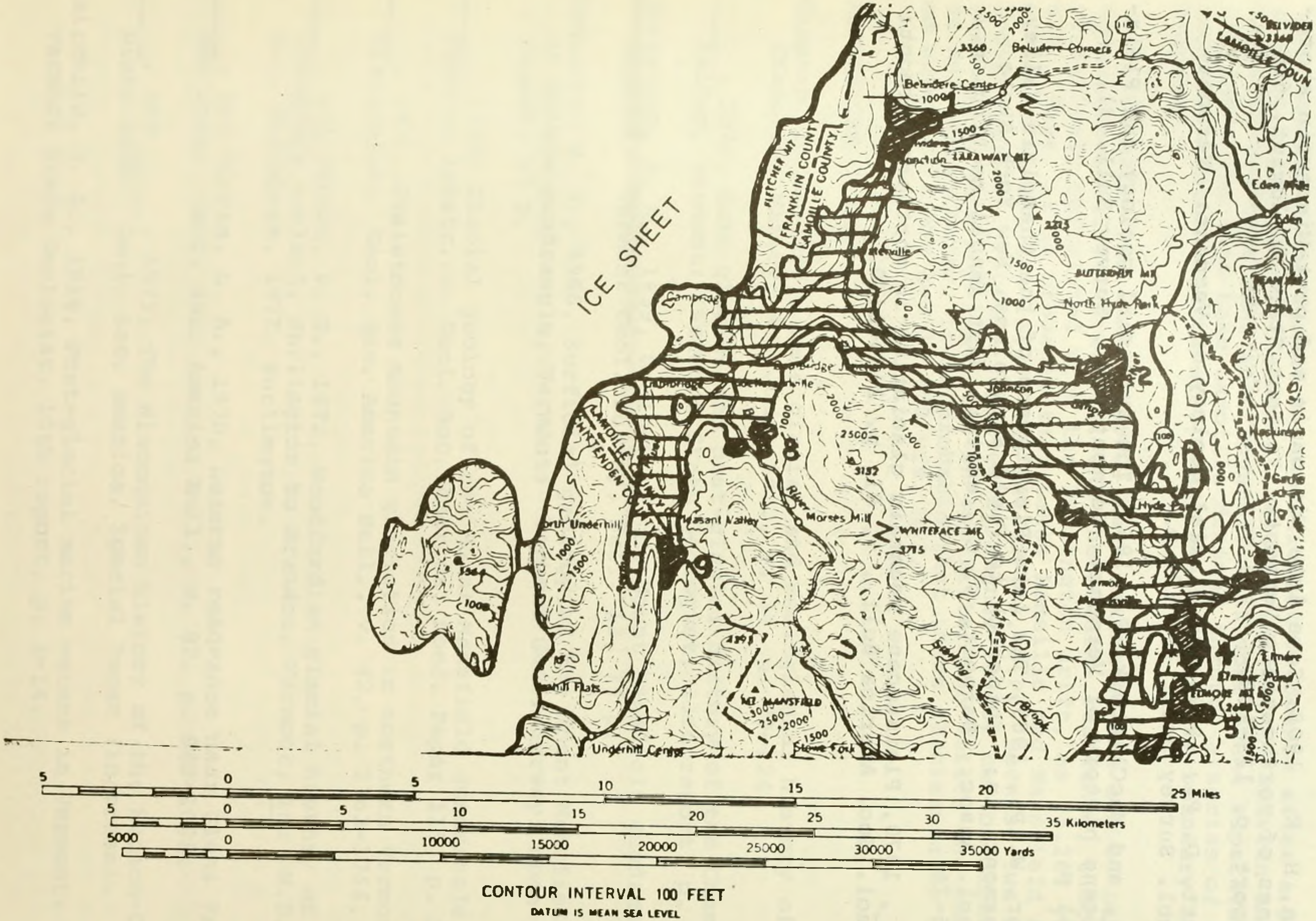

Figure 1. Glacial Lake Lamoille, showing numbered deltas and the probable extent of continental ice that dammed this lake to the west. Numbers correspond to those in Figure 4.

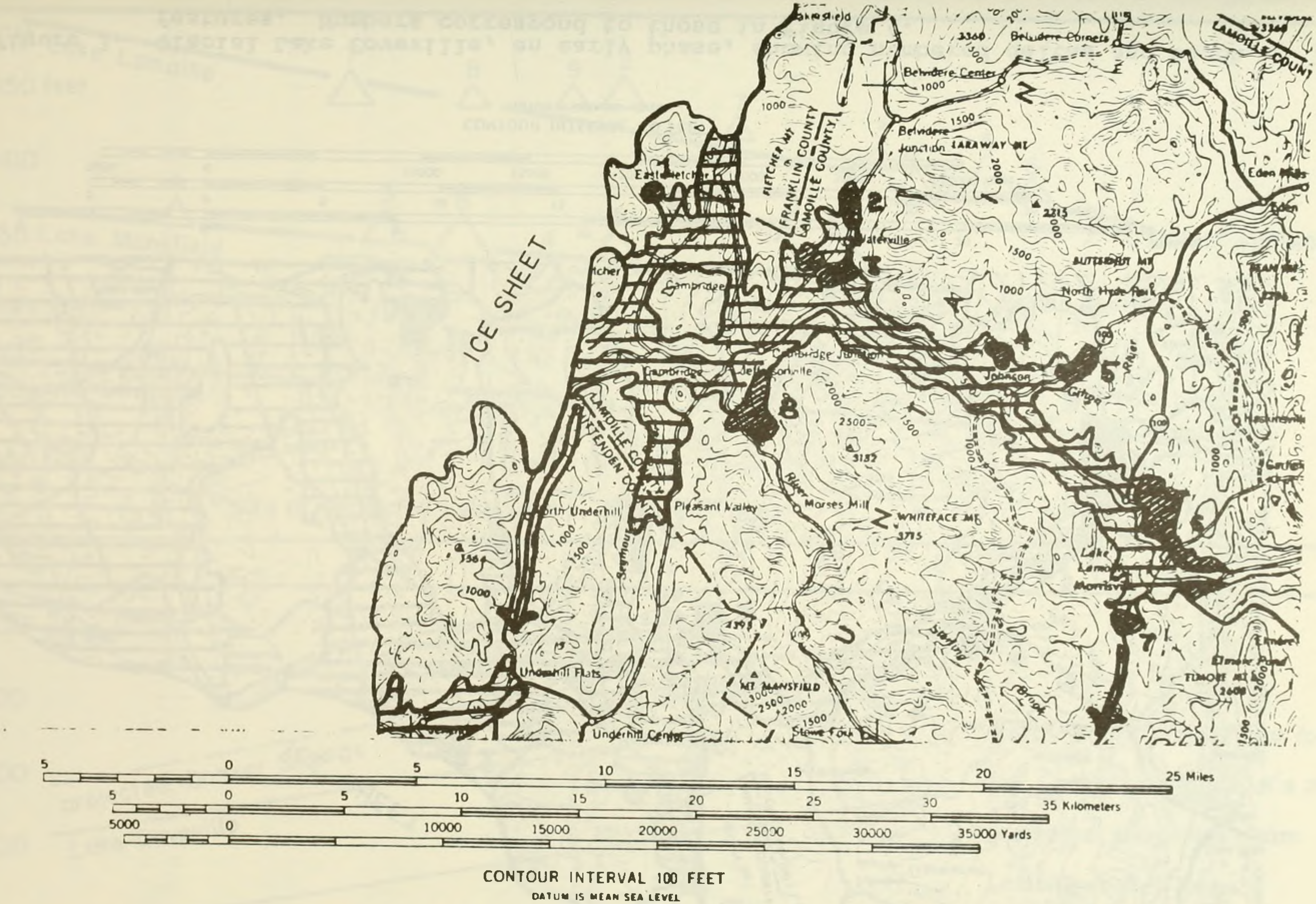

Figure 2. Glacial Lake Mansfield, showing numbered deltas and beach features and the probable extent of continental ice that dammed this lake to the west. Glacial Lake Jericho is also shown southwest of Lake Mansfield and probable drainage lines through The Creek in the west and over the Stowe outlet in the east are depicted by arrows. Numbers correspond to those in Figure 4.

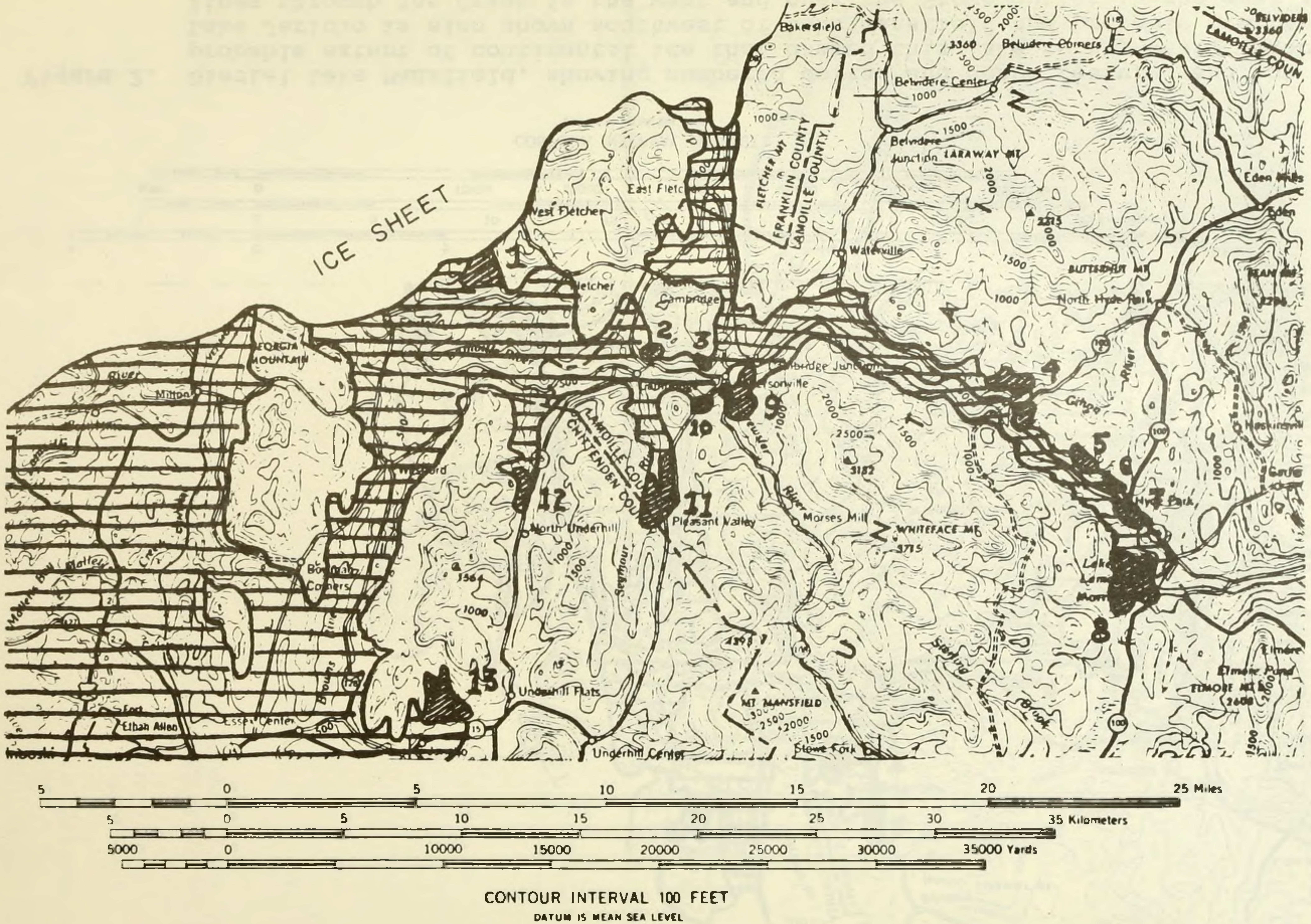

Figure 3. Glacial Lake Coveville, an early phase, showing numbered deltas and beach features. Numbers correspond to those in Figure 4.

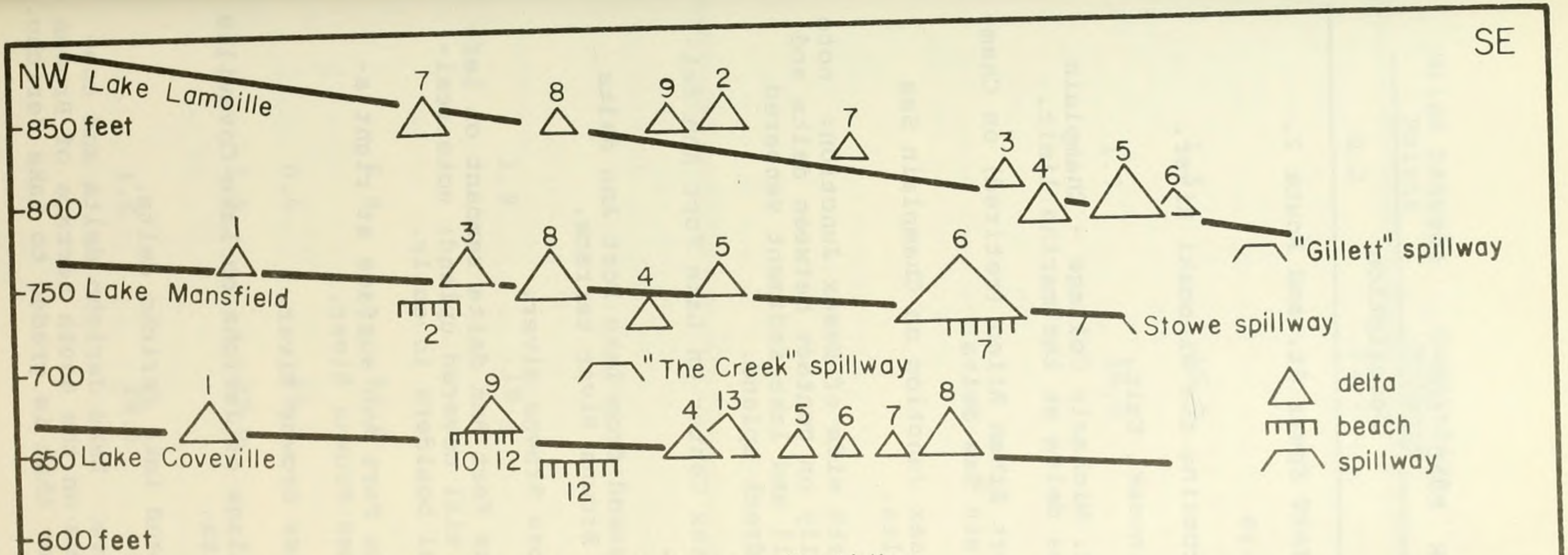

Figure 4. Projected Lake Levels, Lamoille Valley

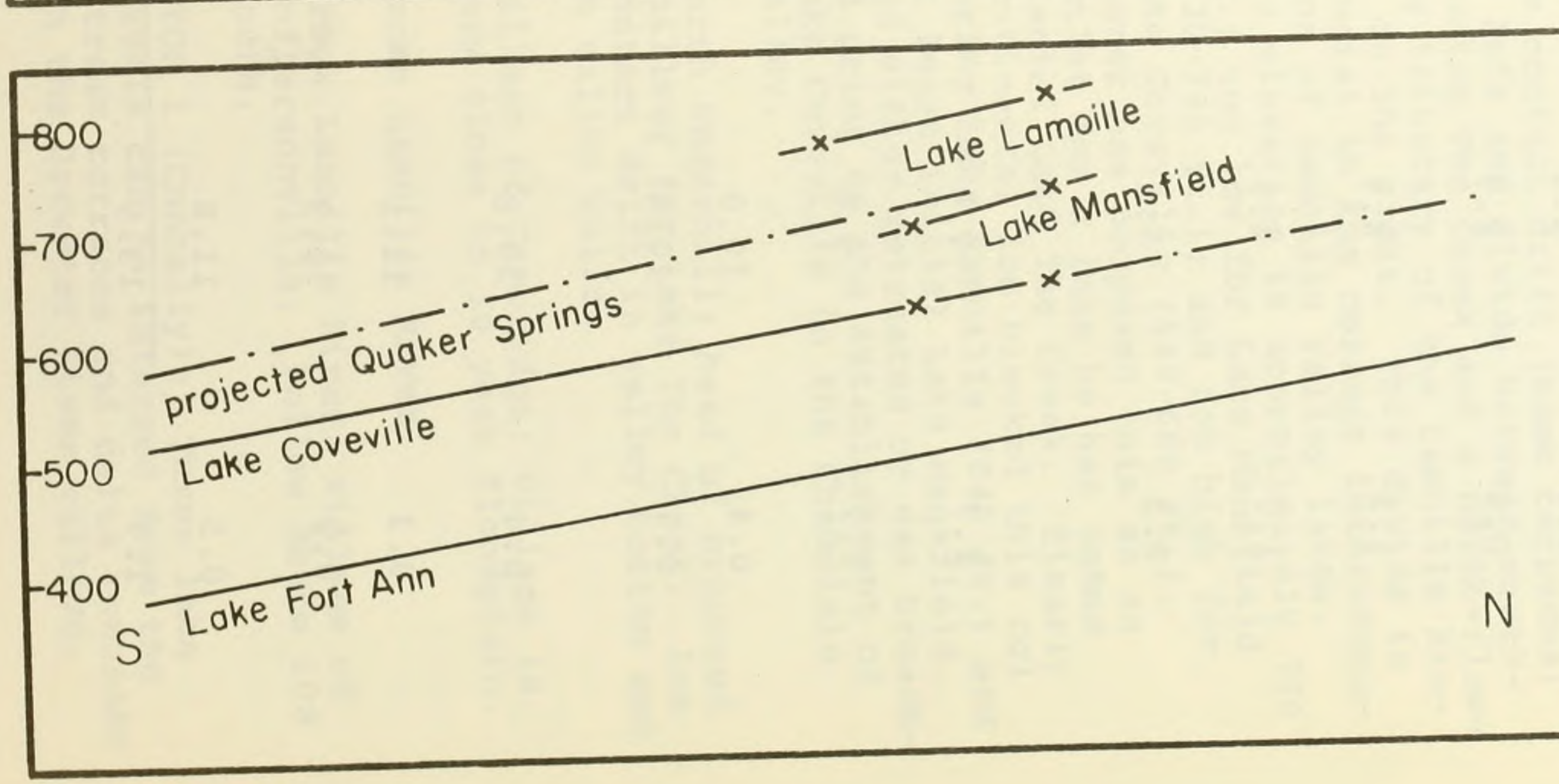

Figure 5.

North-South projections for the Champlain Valley; X's are projected elevations from Lamoille Valley lakes.

CONNALLY - WAGNER ROAD LOG

Miles between Points	Cumulative Mileage	Description
0.0	0.0	START Spear St. and Route 2.
0.3	0.3	I-89
1.2	1.5	Crossing the Winooski River.
0.6	2.1	Winooski Exit.
0.6	2.7	St. Michaels College - Champlain Sea delta at the marine limit.
1.2	3.9	Fort Ethan Allen (retired) on Champlain Sea delta.
1.0	4.9	Essex Junction on Champlain Sea delta.
0.3	5.2	North side of Essex Junction: note gully on contact between delta and till and lake sediment veneered bedrock upland.
2.7	7.9	Essex Center on Lake Fort Ann delta.
1.7	9.6	Descend from Lake Fort Ann delta to Browns River terrace.
0.4	10.0	Cross Browns River.
0.4	10.4	Lake Fort Ann delta remnant on left on till covered upland; note residual boulders in gully.
0.4	10.8	Lake Fort Ann surface at right across Browns River.
0.3	11.1	Cross Browns River.
0.2	11.3	Village of Jericho on Lake Coveville delta.
0.5	11.8	Ascend Lake Jericho delta.
1.7	13.5	Leave Lake Jericho delta and continue on the south terrace of Browns River that is graded to Lake Jericho.

Miles between Points	Cumulative Mileage	Description
0.2	13.7	Cross Browns River and ascend matching terrace on north; village of Underhill. Two sequences of ice contact drift on hillside on right.
1.5	15.2	Cross The Creek; kame terraces on both right and left valley walls.
1.7	16.9	Ice contact drift (kame terraces) on left and divide between south-flowing The Creek and a north-flowing tributary of the Lamoille River on the right. This divide is crucial in the correct interpretation of Lamoille Valley lakes. The elevation is approximately 700 ft.; too low for Lake Mansfield (720-740 ft.); and too high for Lake Coveville (640-660 ft.). Wagner has proposed this as an outlet for a lake he has named Glacial Lake The Creek. Clearly continental ice blocked this col during Lake Lamoille (840 ft.) and at least initial Lake Mansfield, and either retreated or was breached prior to the establishment of Lake Coveville in the Champlain Valley.
1.8	18.7	North Underhill; head of proposed spillway for Lake The Creek. Ice contact drift in valley bottom and on valley walls.
5.8	24.5	Village of Cambridge; village is very close to 10 year floodplain.
0.6	25.1	Cross Lamoille River.
1.9	27.0	Cross Lamoille River; village of Jeffersonville. Follow Route 108 south.
1.6	28.6	STOP 1 (Connally): Three lake levels can be inferred from the stream terraces and delta remnants in the Brewster River valleys.

Miles between Points	Cumulative Mileage	Description
		The lowest surface, to the north, has a sharp slope break at 660 ft. The one on which we stand has a break at 740 ft. Higher terraces are graded to 840 ft. and a small delta remnant may be present at that elevation. The upper level has been assigned to Lake Lamoille, the intermediate to Lake Mansfield, and the lowest to Lake Coveville. Here we will discuss the possible relationship between these lake levels and the The Creek divide.
0.8	29.4	A 20 ft. high erosional scarp in the terraces graded to the 740 ft. delta.
0.8	30.2	Village of South Cambridge; ascend the terrace graded to the 840 ft. level.
1.9	32.1	Gravel pits that showed forset beds in 1965 and bottomset beds in 1970. This delta documents an early local lake at about 1100 ft. dammed by the retreating continental ice margin.
2.6	34.7	Protalus rampart(?) at north entrance to Smugglers Notch; abundant talus and mudslide debris.
2.9	37.6	Stream exposures of ice contact drift and till; collapse structures.
1.0	38.6	Kame deltas(?) or kame moraine(?) in vicinity of Toll House Inn, headwaters of the Waterbury River.
3.8	42.4	Holme Lodge - valley bottom floored with more than 100 ft. of unconsolidated material.
0.2	42.6	Leave Route 108; make sharp right turn and follow signs to Trapp Family Lodge.

Miles between Points	Cumulative Mileage	Description
0.5	43.1	Ten Acres Lodge on 800 ft. delta assigned to Glacial Lake Gillett by Wagner.
1.6	44.7	STOP 2 (Wagner): Trapp Family Lodge. Just beyond Lodge is good view of Miller Brook Valley. Photo stop.
1.7	46.4	Continue on dirt road to black top, make right turn immediately, onto dirt surface. Cross Miller Brook and take first right.
1.8	48.2	STOP 3 (Wagner): Phase I Mountain glaciation. Park cars in field across from house and walk up dirt road onto delta surface. Delta was constructed from outwash with stagnant ice margin up valley. Proceed up valley to Lake Mansfield Trout Club.
2.2	50.4	STOP 4 (Wagner): Phase II Mountain glaciation. Walk across dam breast and follow white blazed trail to lateral moraine. Note swamp area formed between lateral moraine and hillside. Auger holes indicate 11 ft. of peat. Note also boulder in swamp with high water surface marks that show differential rotation. Slightly further down valley is end moraine. In addition to such features as previously reported, other end moraines have now been found at Noyes Pond, Pigeon Pond, Spring Lake, Lakota Lake, and Crook Brook indicating widespread Mountain glaciation in Vermont. Lunch, and then return to cars, proceed back down valley crossing Little River.
8.6	59.0	Join Route 100 north.
2.9	61.9	Stay on Route 100 through Stowe village.

Miles between Points	Cumulative Mileage	Description
3.2	65.1	Bear right leaving Route 100.
1.8	66.9	The first of a series of four deltas, some slightly pitted, that crest between 780 and 800 ft. These have been assigned to Lake Lamoille by Connally and to Lakes Gillett and Stowe by Wagner.
0.9	67.8	Road bends sharply left.
3.6	71.4	Sharp right turn ascending extensive 780 ft. delta deposited by upper Lamoille River.
1.3	72.7	Turn sharply back to left.
0.5	73.2	STOP 5 (Connally): From this vantage point the 780 ft. delta can be seen in the foreground and a partially collapsed or dissected 720 ft. delta can be seen in the distance at Hyde Park. In addition, small deltas are present from Morrisville to Johnson at 640 ft. The upper level is assigned to Lake Lamoille, the intermediate to Lake Mansfield, and the lowest to a Lake Coveville inlet. Wagner has assigned the upper level to Lake Gillett and the intermediate to Lake The Creek. We will discuss the relationship of the three levels to the Lake Gillett spillway. Continue toward Morrisville.
1.0	74.2	Morrisville, turn right on Route 100.
0.2	74.4	Cross Lamoille River.
0.9	75.3	Take Route 15 west.
4.0	79.3	A 740 ft. delta on the south edge of the village of Johnson.

Miles between Points	Cumulative Mileage	Description
0.7	80.0	Bear right on Route 100 in Johnson and continue north.
1.8	81.8	Another dissected 740 ft. delta just east of East Johnson.
1.2	83.0	An extensive delta that crests at 840 ft. was deposited here by the Gihon River.
2.0	85.0	Village of North Hyde Park.
2.7	87.7	Turn left on dirt road; note broad outwash surface.
1.5	89.2	STOP 6 (Wagner): Gravel pit in Phase I Mountain glaciation, Ritterbush Valley.
		Continue northward for 200 ft. and take dirt road to the left.
1.0	90.2	STOP 7 (Wagner): Ritterbush Pond; Phase II Mountain glaciation. Here we will examine the end moraines in Ritterbush Valley.
		Return to dirt road near Stop 6, turn left and continue northward.
1.0	91.2	View through trees to left of Ritterbush Pond cirque.
2.2	93.4	Enter Belvidere Pond cirque.
0.5	93.9	STOP 8 (Wagner): Scenic overlook and parking lot; Phase II Mountain glaciation. This is the Belvidere Pond cirque, "tarn", and end moraine.
		Continue west.
1.4	95.3	Junction Routes 109 and 118. Follow Route 109 south.
2.1	97.4	Gravel pit to left in Phase I Belvidere Valley Mountain glacier features.

Miles between Points	Cumulative Mileage	Description
1.0	98.4	Outwash plain(?).
0.5	98.9	Village of Belvidere Center.
2.1	101.0	STOP 9 (Connally): Pitted outwash is present almost certainly as a result of the Belvidere Pond glacier with possible additions from a local glacier immediately north of the stop. Although the surface elevation is only 800 ft. here it rises to 840 ft. to the north. Thus, Connally assigns this feature to Lake Lamoille, suggesting that local Mountain glaciation can be correlated with Glacial Lake Lamoille. Kettles are not present in Lake Mansfield deposits suggesting a very short-lived episode of local glaciation. Continue south.
3.8	104.8	Village of Waterville.
4.8	109.6	Junction with Route 108. Follow Route 108 south.
0.4	110.0	Junction with Route 15. Follow Route 15 west to Jeffersonville and from there to Burlington.
28.4	138.4	END OF TRIP.