LATE WISCONSINAN LACUSTRINE AND MARINE ENVIRONMENTS IN THE CHAMPLAIN LOWLAND, NEW YORK AND VERMONT

by

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INTRODUCTION

The Champlain Sea was a Late Wisconsinan marine incursion into the isostatically depressed St. Lawrence and Champlain Lowlands following ice recession from the eastern St. Lawrence Lowland (ca. 12.5 to 10.0 ka (kilo anno)). The marine episode followed a freshwater proglacial lacustrine interval in the Champlain and western St. Lawrence Lowlands (Fulton and others, 1987; Chapman, 1937). Sedimentary sequences containing till, ice-contact gravel, subaqueous outwash, and sparsely fossiliferous lacustrine sediment overlain by fossiliferous marine sediment record the transition from glacial to lacustrine to marine conditions in the basin.

This trip will examine the nature of the transition from freshwater to marine conditions and the paleoenvironments of the Champlain Sea as shown by the lithostratigraphic and biostratigraphic records in the Champlain Lowland. Faunal assemblages are used to reconstruct the areal and temporal distribution of water temperature and salinity within the basin. Emphasis is placed on the microfauna, particularly the ostracodes, and how changing microfaunal assemblages record environmental changes in this part of the Champlain Sea. The data summarized here are taken primarily from detailed faunal studies of foraminifers (Cronin, 1979) and ostracodes (Cronin, 1981) which concentrated in the southern arm of the sea in the Champlain Lowland of northwestern Vermont, northeastern New York, and southern Quebec. It should be stressed, however, that the sequence of faunas found in this region are not necessarily the same as those in other parts of the Champlain Sea where different hydrologic conditions caused a distinctly different sequence of paleoenvironments (Rodrigues and Richard, 1986; Rodrigues, 1987).

PHYSIOGRAPHIC AND GEOLOGIC SETTING

Late glacial ice flow and deglacial sedimentary environments in the northern Champlain Lowland were influenced by the regional physiography. The St. Lawrence and Champlain lowlands form a broad, contiguous lowland underlain by Cambrian and Ordovician sedimentary rocks (Fig. 1). The lowlands are bounded on the north and southwest by the Precambrian metamorphic rocks of the Laurentian Highlands and the Adirondack Upland, respectively, and on the

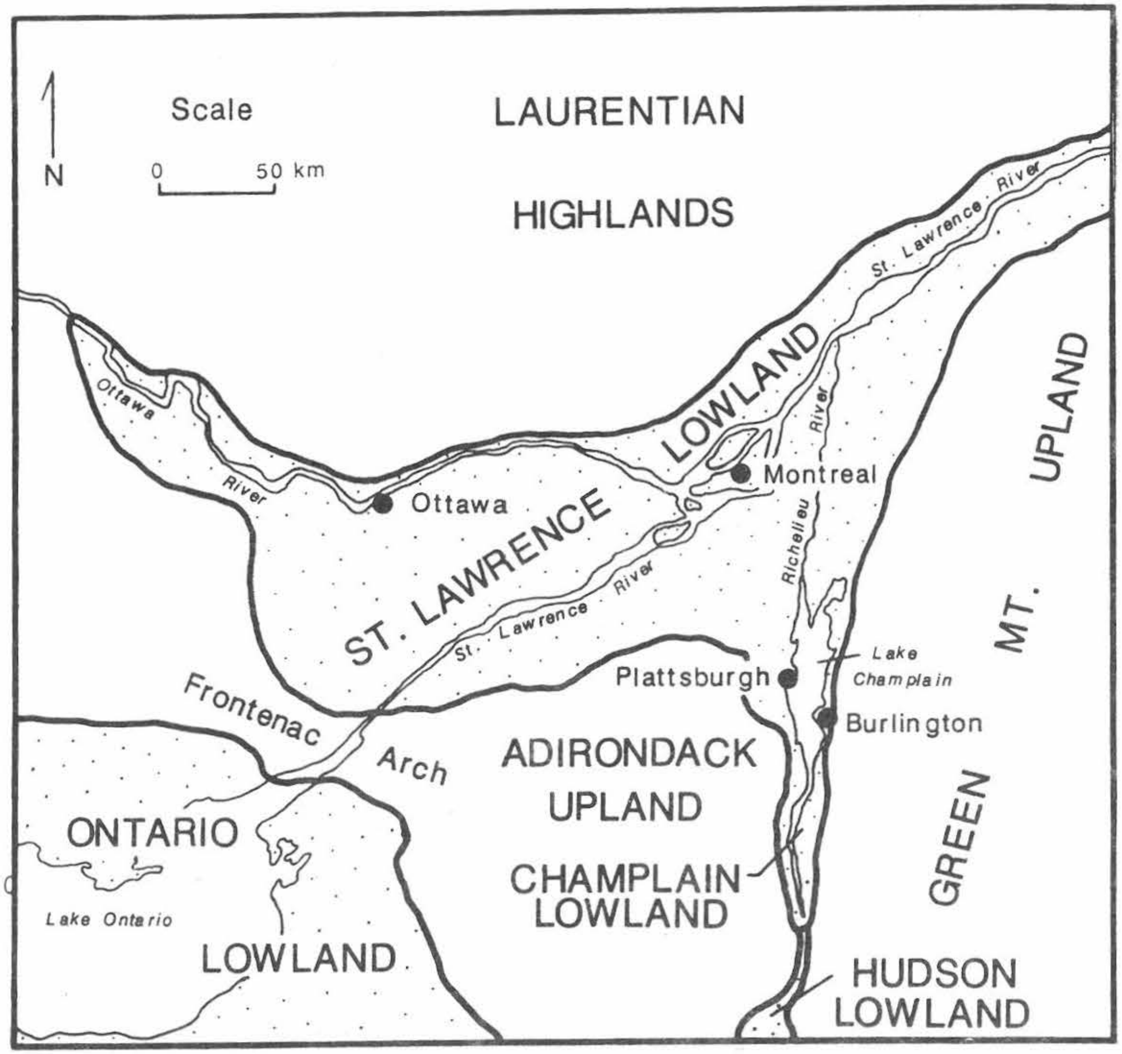

Figure 1. Physiographic map of the Champlain and St. Lawrence lowlands region.

southeast by the Precambrian and Lower Paleozoic metamorphic rocks of the Green Mountain Uplands. The Champlain Lowland narrows to the south where it merges with the Hudson-Mohawk Lowland.

Late Wisconsinan ice flow was concentrated in the lowland regions creating terrestrial ice streams (Hughes and others, 1985). One ice stream flowed southward through the Champlain and Hudson lowlands, while a larger ice stream flowed southwestward through the St. Lawrence and Ontario lowlands. Deglacial drawdown of ice into lowland ice streams caused thinning of ice in uplands and lobation of the ice front. Analyses of striae, drumlins, grooved drift, and dispersal trains in the Champlain Lowland and adjacent uplands generally conform to a model of southward flow at the Late Wisconsinan glacial maximum and more complex localized flow patterns during deglaciation (Denny, 1974; Ackerly and Larsen, 1987). The local flow patterns are associated with the formation of the Hudson-Champlain Lobe during deglaciation.

Digitate secondary lobes along the margin of the Hudson-Champlain Lobe penetrated tributary valleys and created local upland proglacial lakes. The drainage chronologies of these impoundments are complex and imcompletely understood. Documentation of upland proglacial lakes in the northeastern Adirondack region includes work by Alling (1916), Denny (1974), Clark and Karrow (1984), Diemer, Olmsted, and Sunderland (1984), and Diemer and Franzi (this volume). Upland-lake studies in northwestern Vermont include Stewart and MacClintock (1969), Connally (1972), and Larsen (1972, 1987).

DEGLACIATION OF THE CHAMPLAIN LOWLAND

Recent investigations in the Champlain lowlands (Connally and Sirkin, 1971, 1973; Parrott and Stone, 1972; Denny, 1974; Connally, 1982; DeSimone and LaFleur, 1986) favor a deglacial model that involves a single Late Wisconsinan glaciation followed by stagnation-zone retreat that may have been interrupted by minor ice-front oscillations. The terminus of the Hudson-Champlain Lobe lay in deep, proglacial lakes that expanded northward with ice recession. Backwasting of the ice front was probably enhanced by calving. Deposits of till, subaqueous outwash, and ice-contact stratified drift record the passing of the ice front during its northward retreat (Denny, 1974; DeSimone and LaFleur, 1986).

Minor readvances of the ice front in the Champlain Lowland have been proposed based upon morphologic relationships of glacial and lacustrine landforms and stratigraphic sequences containing intercalated glacial, lacustrine, and marine sediments (Table 1). The Luzurne (ca. 13.2 ka) and Bridport (ca. 12.8 ka) readvances were documented by Connally and Sirkin (1971, 1973). DeSimone and LaFleur (1986) have questioned the validity of the Luzurne readvance based upon their reconstructed ice margins in the northern Hudson Lowland. Wagner (1972) presented evidence for a minor readvance in the northern Champlain Lowland that may have temporarily reestablished freshwater conditions following the initial formation of the Champlain Sea. Denny (1974) proposed that several ice-front oscillations near Covey Hill alternately opened and closed drainage from proglacial lakes in the St. Lawrence basin to the Champlain Lowland. The discharge events removed previously deposited sediment and produced large areas of bare rock such as Flat Rock, near Altona.

Table 1. Comparison of lacustrine and marine water levels and biostratigraphy in the St. Lawrence and Champlain lowlands.

Lacustrine & Marine Water Levels			Biostratigraphy
St. Lawrence Lowland[1]	Champlain Lowland[2]		Champlain Lowland[3]
	Lake Champlain		
	Champlain Sea	Port Henry	
		Plattsburgh	*Mya* Phase
		Burlington	
		Port Kent	*Hiatella arctica* Phase
Level V		Beekmantown	
		Upper Marine Limit	Transitional Phase
Level IV			
Level III			
	Lake Fort Ann (multiple levels proposed)		
Level II			Nonmarine
Level I			
	Lake Coveville		

1. Clark and Karrow (1984)
2. Chapman (1937); Wagner (1972); Denny (1974)
3. Elson (1969); Cronin (1977)

PROGLACIAL WATER BODIES

Chapman (1937) proposed a generalized chronostratigraphic framework of proglacial lake stages in the Hudson and Champlain lowlands. Chapman recognized two principal stages of Lake Vermont in the Champlain Lowland, the Coveville and Fort Ann stages, named for their presumed outlet channels (Fig. 2). An earlier stage, the Quaker Springs Stage, proposed by Woodworth (1905), was reintroduced by later authors (e.g. LaFleur, 1965; Stewart and MacClintock, 1969; Wagner, 1972; Connally and Sirkin, 1973). LaFleur (1965) demonstrated that the Quaker Springs, Coveville, and Fort Ann lake stages in the Champlain Lowland were contiguous with impoundments in the Hudson Lowland. Connally and Sirkin (1973) recommended that use of the name Lake Vermont be discontinued and that the previously defined stages be considered as independent lake levels. Other modifications to Chapman's deglacial lake sequence have been proposed (e.g. Wagner, 1972; Connally, 1982; DeSimone and LaFleur, 1986) and these are summarized in Table 1. Denny (1974) and Clark and Karrow (1984) discussed drainage relationships between lakes in the St. Lawrence and Champlain lowlands (Table 1).

The freshwater proglacial lakes persisted until continued northward ice recession allowed marine water to inundate the isostatically depressed St. Lawrence and Champlain lowlands (Fig. 3). Stratified sediment containing marine fossils documents the marine episode, which is referred to as the Champlain Sea. The oldest radiocarbon dates from shell material within the Champlain Valley include 11.7 ka (Parrott and Stone, 1972), 11.8 ka (GSC 2338) and 11.9 ka (GSC 2366) (Cronin, 1979). The Champlain Sea episode has been subdivided based upon the regional distribution of shoreline deposits (Chapman, 1937) and the temporal distribution of faunal assemblages (Elson, 1969; Cronin, 1977; Rodrigues and Richard, 1986). Regression of marine water from the region was caused by isostatic uplift and ended with the establishment of Lake Champlain, ca. 10.0 ka.

Stratified sediments of variable thickness and composition were deposited into the proglacial lake and marine water bodies in the Champlain Valley during deglaciation. Littoral zone sedimentation is characterized by extensive fluviodeltaic sandplains, cobbly to bouldery beach deposits, wave-cut and wave-built terraces, and spits (Chapman, 1937; Denny, 1974). Fine-grained sediment was deposited in deeper water and in quiet-water embayments. Bathymetric lows served as sediment sinks and accumulated thick sequences of bottom sediment, ice-rafted debris, and sediment-flow deposits.

PALEOZOOGEOGRAPHY OF THE CHAMPLAIN SEA

The faunal assemblages of the Champlain Sea have been the subject of studies for over 150 years and continue to receive attention today. Among the most notable paleontologic studies are those of the dwarfed or stunted molluscan fauna by Goldring (1922), the marine mammals by Harington (1977), the macroinvertebrates by Wagner (1970), and the benthic microfaunas, especially the

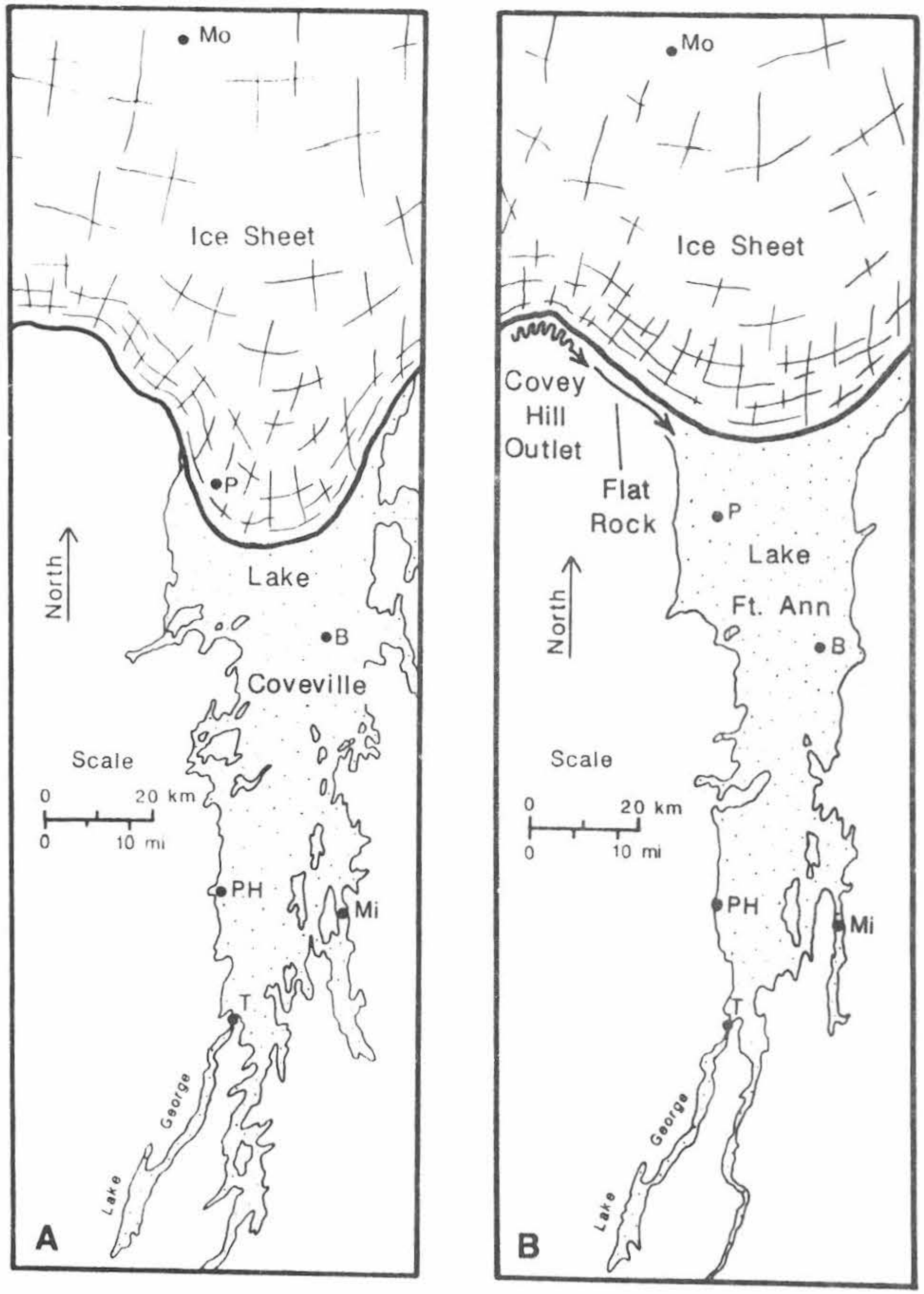

Figure 2. Proglacial lakes in the Champlain Lowland. A) Lake Coveville at its maximum extent. B) Lake Fort Ann showing eastward drainage from Lake Iroquois through the Covey Hill spillway. (After Chapman, 1937; Connally and Sirkin, 1973; and Denny, 1974). Mo- Montreal, P- Plattsburgh, B- Burlington, PH- Port Henry, Mi- Middlebury, T- Ticonderoga.

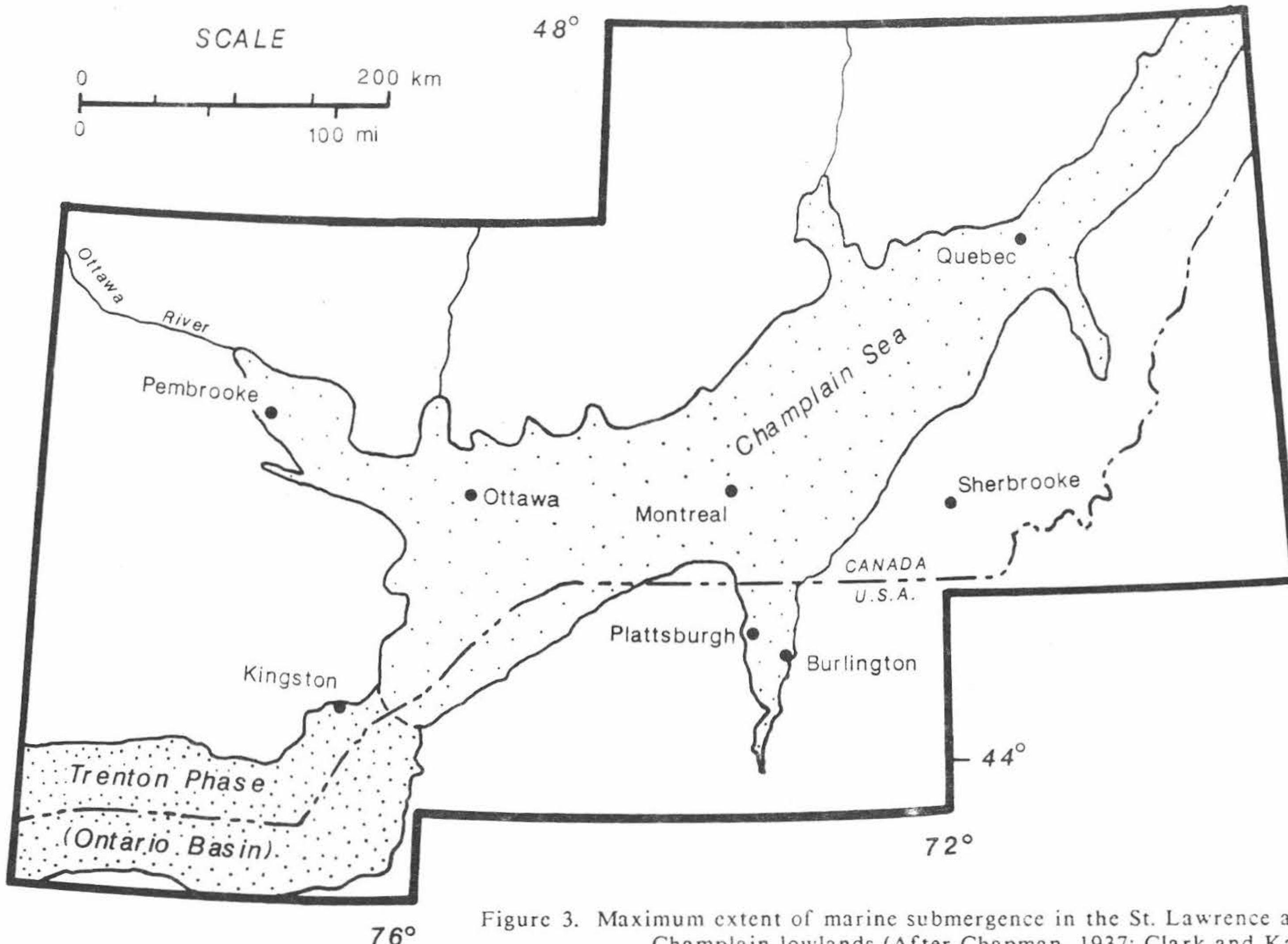

Figure 3. Maximum extent of marine submergence in the St. Lawrence and Champlain lowlands (After Chapman, 1937; Clark and Karrow, 1984; Fulton and others, 1987).

foraminifers and ostracodes (Cronin, 1979, 1981; Guilbault, 1980; Rodrigues and Richard, 1986; Rodrigues, 1987). Wagner (1967) listed published references to the Champlain Sea faunas from 1837 to 1966, while Cronin (1981) and Rodrigues and Richard (1986) provide references to more recent work.

Postglacial faunas from northeastern North America

Ostracodes from the eastern Goldthwait Sea of western Newfoundland, the western Goldthwait Sea of Quebec, the Presumpscot Formation of Maine, and the Boston "blue clay" of Massachusetts have been studied and compared to ostracodes from three regions of the Champlain Sea; the southern region in the Champlain Lowland, the western region in eastern Ontario, and the eastern region between Montreal and Quebec City (Cronin, in press). Intraregional and extraregional comparisons of the ostracode assemblages were made using the binary Otsuka coefficient of faunal similarity. The results showed that three of the four highest similarities were among the three Champlain Sea regions. Within the Champlain Sea regions, the highest similarity between the western and southern regions was highest and that between the eastern and western regions was next highest. The third highest similarity was found between the faunas from the eastern Champlain Sea and the western Goldthwait Sea.

The results indicate that the Champlain Sea faunas are distinct from other postglacial faunas because of the predominance of eurytopic species and the presence of non-marine taxa. Atlantic coast postglacial ostracode assemblages are distinct and reflect their location adjacent to open North Atlantic water. The results also indicate that the constriction in the St. Lawrence Lowland near Quebec City did not serve as a barrier for marine invertebrates since the assemblages from the eastern Champlain and Goldthwait seas are similar.

Extraregional Comparisons

The combined postglacial ostracode fauna of northeastern North America, including the Champlain Sea, was compared to other high latitude faunas (Cronin, in press) to provide a large-scale zoogeographical perspective. The northeastern North American faunas display the highest similarity to the modern fauna at Novaya Zemyla, with 29 species in common. A relatively low but still significant similarity was observed between the North American postglacial faunas and the Late Pliocene fauna of the Daishaka Formation of northern Honshu, Japan recently studied by Tabuki (1986). The Daishaka Formation contains a cold water marine fauna, the Omma-Manganji fauna, that represents an interval of cool climate during which high latitude species migrated southward as they did in the western North Atlantic during glacial periods. Cronin and Ikeya (1987) recently studied the Omma-Manganji fauna from other formations in Japan and found at least 26 circumpolar ostracode species common to both the western North Pacific and North Atlantic oceans. At least 11 ostracode species occurring in the Omma-Manganji fauna also occur in the Champlain Sea deposits and another 10 species occur in the Goldthwait Sea deposits and the Presumpscot Formation.

In summary, the microfaunal record of the Champlain Sea has not only provided important insight into local and regional paleoenvironments during the final withdrawal of continental ice from the Champlain Lowland region it also contains important information concerning the evolution and paleozoogeography of circumpolar species.

DESCRIPTION OF FIELD TRIP LOCALITIES

STOP #1: Town Gravel Pit, Isle LaMotte, Vermont

The predominant lithofacies consists of thinly bedded, molluscan-rich sand with minor gravelly sand and sandy to silty mud interbeds. The sands are generally medium to coarse grained and are cross bedded or horizontally laminated. Individual beds range from a few centimeters to about 20 cm thick and can be traced laterally for several meters. The sandy facies contains two biofacies, a Macoma balthica facies and a Mytilus edulus facies. The faunal assemblages were previously described by Cronin (1977 (loc. 11), 1979, 1981 (loc. 33)). Articulated valves of both species are commonly found in living position. Occurrences of Mytilus in living position in Champlain Sea deposits are rare since this mollusc usually lives attached to the substrate by a byssus and its two valves have an adont hinge that disarticulates easily.

Ostracodes and benthic forminifers are rare in these sands. The following species occur;

Cyprideis sp.
Cythere lutea (Mueller, 1785)
Cytheromorpha macchesneyi (Brady and Crosskey, 1871)
Cytheropteron latissimum (Brady, Crosskey, and Robertson, 1874)
Cytherura gibba (Mueller, 1875)
Eucythere declivis (Norman, 1865)
Finmarchinella logani (Brady and Crosskey, 1871)
Heterocyprideis sorbyana (Jones, 1857)
Ilyocypris gibba (Rahmdohr, 1808)
Leptocythere quebecensis (Cronin, 1981)
Palmenella limicola (Norman, 1865)
Sarsicytheridea bradii (Norman, 1865)
Sarsicytheridea macrolaminata (Elofson, 1939)
Sarsicytheridea punctillata (Brady, 1865)
Semicytherura cf. similis (Sars, 1865)

These deposits probably represent the latest phase of the Champlain Sea in this region known as the Mya arenaria Phase (Elson, 1969; Cronin, 1977). Mya arenaria is absent at this locality because it is usually found in clay substrates in low-lying areas west of Lake Champlain. Based on modern temperature tolerances of the ostracode species, the annual temperature range is estimated to have been about 0^{o} to 20^{o}C. Salinities during the Mya Phase were oligohaline to mesohaline (1 to 18 ppt) and all the ostracode species occurring at the Isle LaMotte locality tolerate, and often thrive in brackish water environments.

A coarse gravel facies that contains decimeter-scale foreset beds that range from poorly sorted coarse pebbly sand to open-work cobble gravel was recently exposed in a small excavation at the south end of the pit. The facies contains marine fossils that are commonly disarticulated and fragmented. The gravel facies underlies the fossiliferous sand facies described above and may be related to coarse gravel in an excavation 0.5 km to the west. Gravel foresets at both localities indicate a southward to southeastward paleocurrent. It is difficult to reconstruct the sedimentary environment that existed at the time the gravel facies was deposited because of the limited extent of the exposure at this locality. The gravel facies may be related to a high-energy littoral marine environment during the late regressive phase of the Champlain Sea. Alternatively, it may represent ice-proximal subaqueous outwash that was deposited during ice recession or possibly an ice readvance. A readvance of this nature had been previously proposed by Wagner (1972) based upon stratigraphic evidence from northwestern Vermont.

STOP #2: Beach Ridges of the Champlain Sea, Sciota, New York

The ridges consist of coarse, flaggy gravel that is derived from the underlying Potsdam Sandstone. Outcrops of sandstone can be observed in drainage ditches nearby and presumably bedrock underlies the ridges at a shallow depth. These ridges were mapped and described by Denny (1970, 1974) who traced them over a distance of 0.3 km. They trend roughly north-south but curve westward at their northern ends along the margin of a former headland. The elevations of the ridge crests lie between 91 and 98 m.

STOP #3: Ingraham Esker, Ingraham, New York

The sedimentology and stratigraphy of the Ingraham Esker was summarized by Denny (1972, 1974) and more recently by Diemer (in press). The esker consists predominantly of upwardly fining subaqueous outwash that was deposited in a series of esker fans at the terminus of the northward retreating ice front. The ridge is overlain by fresh water rhythmites which are in turn conformably overlain by a massive mud facies. Diemer (in press) attributes the massive mud facies to an early, transitional phase between fresh (Lake Fort Ann) and marine conditions (Champlain Sea). The section is unconformably overlain by coarse, fossiliferous gravel that probably represents wave-reworking of the previously deposited sediment during the marine regression. Denny (1972, 1974) attributed the low relief of the ridge to extensive wave erosion, however, Diemer (in press) suggests that the morphology of the ridge is a consequence of its origin as subaqueous outwash.

The faunal assemblages at this locality were described by Cronin (1977, loc. 18; 1979, 1981, loc. 4). Hazel studied ostracodes from several localities in the esker and found a total of nine species (in Denny, 1972). The esker's faunas represent the Hiatella artica Phase of the Champlain Sea (Elson, 1969; Cronin, 1977) which occurred between 11.6 to 10.6 ka The following ostracodes were found at this locality in the shelly marine gravels that cap the rhythmite facies.

Candona sp.
Cythere lutea (Mueller, 1785)
Cytheromorpha macchesneyi (Brady and Crosskey, 1871)
Cytheropteron champlainum (Cronin, 1981)
Cytheropteron latissimum (Norman, 1865)
Finmarchinella logani (Brady and Crosskey, 1871)
Heterocyprideis sorbyana (Jones, 1857)
Sarsicytheridea bradii (Norman, 1865)
Sarsicytheridea punctillata (Brady, 1865)

The annual range of bottom-water paleotemperature was probably 0^{o} to 12^{o}C and salinities were polyhaline, between 18 and 30 ppt, as indicated by the faunal assemblages. This salinity was the closest to normal marine conditions that was reached in this part of the Champlain Sea, at least for shallow-water environments.

STOP #4: Korths Farm Section, East Beekmantown, New York

This stop will involve two sections along the east bank of Ray Brook. Cronin (1977, loc. 34; 1979, 1981, loc. 84) described the faunal assemblages from the northern section approximately 100 m upstream from the Korths Farm road. Marine clays (formerly known as the Leda clay) overlie rhythmites and contain the mollusc Portlandia arctica and the following ostracodes;

Cytheromorpha macchesneyi (Brady and Crosskey, 1871)
Cytheropteron latissimum (Brady, Crosskey, and Robertson, 1874)
Heterocyprideis sorbyana (Jones, 1857)
Sarsicytheridea bradii (Norman, 1865)
Sarsicytheridea macrolaminata (Elofson, 1939)
Sarsicytheridea punctillata (Brady, 1865)

The faunas at this locality represent the Transitional Phase of the Champlain Sea (Cronin, 1977), which has been dated between 11.6 and 12.0 ka, however, the age for the earliest marine inundation in the region is not yet certain. The bottom-water temperatures ranged annually from about -2^{o} to 10^{o}C. Normal marine and polyhaline ostracodes are absent from the Transitional Phase and salinities fluctuated between 0 and 18 ppt. The term "Transitional Phase" was given to this interval because the faunas indicate a lacustrine to marine transition during which there was mixing of pre-Champlain Sea freshwater with the earliest influx of marine water that entered the region via the St. Lawrence estuary.

The southern section, 50 m downstream from the Korths Farm road, resulted from recent cutbank erosion. Approximately 3 m of flow-slide colluvium, derived primarily from the marine clay unit described above, overlie intact marine clay. The base of the colluvium is marked by an erosional unconformity that includes buried logs. The freshwater rhythmites were not observed at this section but may occur on or below the stream bed. Geomorphological evidence for other flow-slides exists throughout this part of the Ray Brook valley.

STOP #5: Slump-earthflow, Whallonsburg, New York

The Whallonsburg slump-earthflow (Fig. 4) occurred during the night of 28 July, 1987, following localized, light to moderate thunderstorm activity. The slump involved the eastward displacement of 0.9 ha of Pleistocene lacustrine sediment on a cutbank of the Bouquet River. This portion of the Bouquet Valley has a history of landslide activity (Newland, 1938; Whitcomb, 1938; Buddington and Whitcomb, 1941). The 1987 Whallonsburg slump was described by Franzi, Bogucki, and Allen (1988).

The slump is roughly rectangular in plan with an average length of 85 m and an average width of 110 m. The crown is 16 m above stream level. A 0.2 ha toe bulge, composed of highly plastic clay and alluvial sediment, was raised to a height of 4.5 m in the stream channel. The slump consists of a primary mass that was involved in the initial slump and two smaller retrogressive slumps (Fig. 4).

The slump exposed 0.5 to 1 m of coarse sand and gravel over 4 m of nonfossiliferous lacustrine clay and silt at the headscarp. The lacustrine section is estimated to be 23 m thick based upon seismic refraction data from the crown. The clays are characterized by high plasticity and natural water content with low bulk density and shear strength (Fig. 5). The lacustrine unit grades upward from soft, blue-gray, thinly laminated, clay and clayey silt rhythmites to stiff, brown, thinly bedded silt and clay. The textural variation probably reflects the effects of shoaling or infilling during the waning stages of the lake's history. The overlying gravel is part of a large terrace that may be graded to Late Pleistocene marine deltas near Willsboro.

Hillslope reconstructions based on slide-deposit morphometry and laboratory analysis of the long-term shear strength of undisturbed clay samples were used to determine the geological controls on slope stability (Franzi, Bogucki, and Allen, 1988). The factor of safety (FS = resisting forces/driving forces) of the reconstructed preslide slope was calculated using the slope stability model STABR (Duncan and Wong, 1985) under a range of "likely" pore pressure conditions. The results indicate that the preslide factor of safety was close to the threshold value of 1.0 (range 1.0 to 1.2). Although the slump may have been triggered by the rainstorm activity, the actual cause is probably related to pore pressure conditions at the clay-bedrock contact and long-term processes such as cutbank erosion at the toe of the slope and fissure development in the upper, overconsolidated clay.

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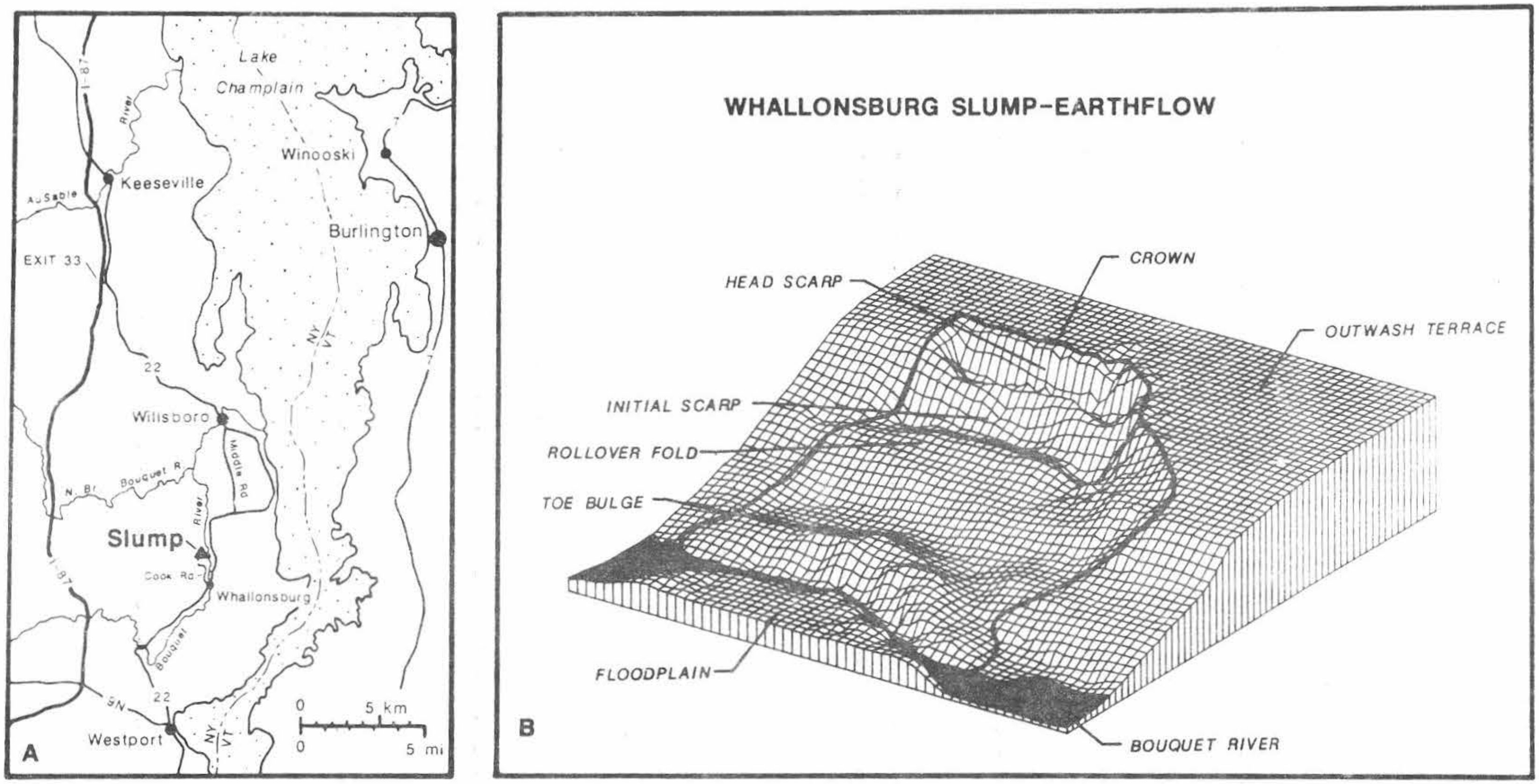

Figure 4. The Whallonsburg slump-earthflow. A) Location map. B) Block diagram showing the major morphological features (From Franzi, Bogucki, and Allen, 1988).

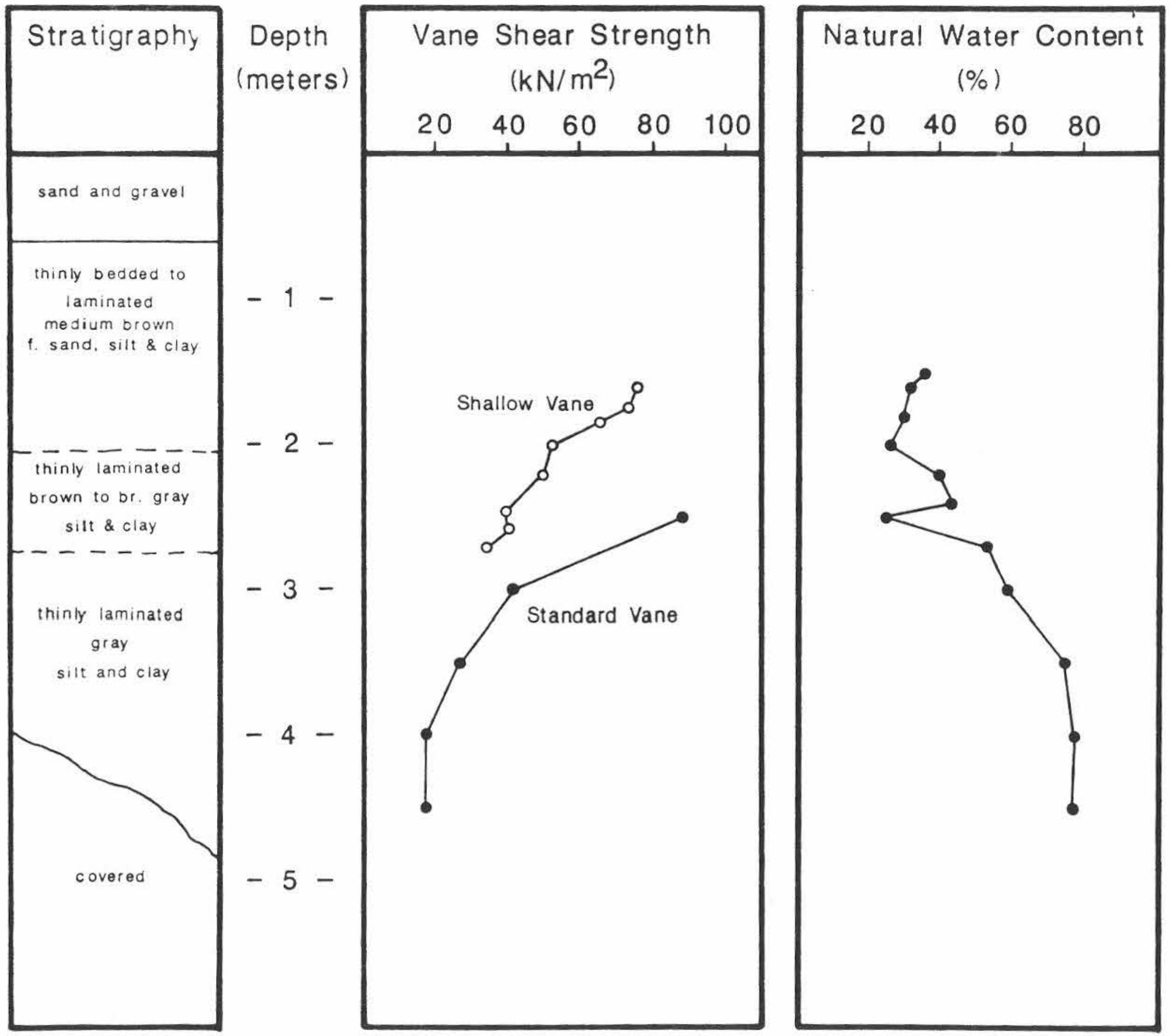

Figure 5. Vane shear strength and natural water content of lacustrine sediment exposed at the headscarp of the slump-earthflow near Whallonsburg (Franzi, unpub. data).

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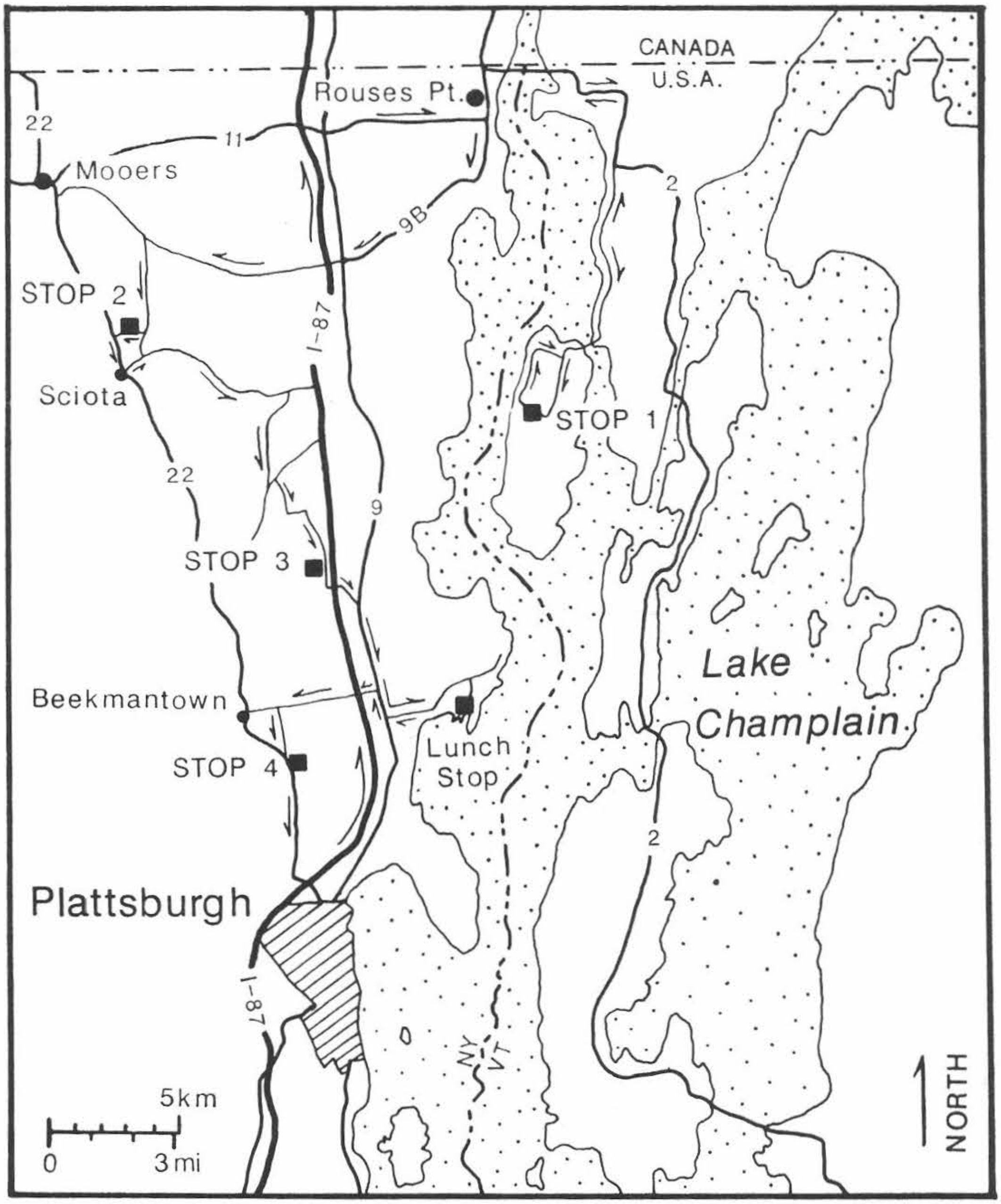
ROAD LOG

CUM. MILES	MILES F.L.P.*	DESCRIPTION**
0.0	0.0	Assemble in the west parking lot of Hudson Hall on the P.S.U.C. campus. Leave parking area, turn right at entrance, and proceed northwestward on Broad St.
0.1	0.1	Traffic light, continue northwestward on Broad St.
0.2	0.1	Traffic light, continue northwestward on Broad St.
0.4	0.2	Traffic light at intersection of Broad and Cornelia streets. Bear left onto Cornelia and proceed westward. Continue westward on Cornelia St. through two traffic lights.
1.1	0.7	Junction I-87 North; Turn right onto entrance ramp and proceed northward to Exit 42 in Champlain.
6.3	5.2	Outcrop of the Cumberland Head argillite.
14.4	8.1	Outcrop of the Chazy Gp.
21.8	7.4	Exit 42, Champlain, N.Y.; Exit I-87 and proceed to the Route 11 intersection.
21.9	0.1	Turn right onto Route 11 and proceed eastward to Rouses Point.
23.1	1.2	Bridge over Great Chazy River.
26.6	3.5	Intersection of Routes 11 and 9B. Turn left at stop sign and proceed northward through the village of Rouses Roint.
27.7	1.1	Intersection of Routes 11, 9B and 2. Turn right and proceed eastward toward the Korean Veterans Memorial Bridge.
28.3	0.6	Korean Veterans Memorial Bridge (formerly Rouses Point Bridge). The ruins of Fort Blunder (Ft. Montgomery), an American fort that was originally built on Canadian soil, can be seen on your left. The "blunder" was corrected by moving the border northward.

*From last point
** Refer to Fig. 6 for stops 1-4 and Fig. 4A for stop 5.



Trip Route

Figure 6. Location map for field-trip localities 1-4.

CUM. MILES	MILES F.L.P.	DESCRIPTION
28.6	0.3	Vermont state line. Continue eastward on Route 2 to the village of Alburg.
32.2	3.6	Alburg, Vermont.
33.3	1.1	Route 2 bears to the left; turn sharply right onto unmarked road and proceed southward along lake shore.
37.5	4.2	Outcrop of Stony Point argillite.
37.7	0.2	Intersection of unmarked road and Vermont Route 129. Turn right at stop sign and proceed southward across causeway to Isle LaMotte.
40.3	2.6	Route 129 ends in the village of Isle LaMotte at a crossroad. Turn right adjacent to a large, gray limestone building onto unmarked road and proceed westward.
40.7	0.4	STOP #1. Isle LaMotte Landfill.
41.1	0.4	Gravel pit. Coarse gravel foresets indicating a southerly paleocurrent are exposed in the working face of the pit.
41.2	0.1	Stop sign at a "T" intersection. Turn right and proceed northward along the lake shore.
42.3	1.1	St. Anne's Shrine. The road takes a 90^{0} turn to the right (east) immediately north of the shrine entrance.
43.3	1.0	Intersection of unmarked road and Vermont Route 129. Turn left at stop sign and proceed northward on Route 129.
44.3	1.0	Isle LaMotte causeway. Continue northward across causeway on Route 129.
44.4	0.1	Intersection with unmarked road. Turn left onto unmarked road and proceed northward along the lake shore to Alburg.
48.7	4.3	Intersection of unmarked road and Route 2 in Alburg. Turn left onto Route 2 and proceed northward through town.
53.7	5.0	Korean Veterans Memorial Bridge. Continue eastward across bridge to Rouses Point, New York.

CUM. MILES	MILES F.L.P.	DESCRIPTION
54.2	0.5	Intersection of Routes 2, 11, and 9B. Turn left and proceed southward on Routes 11 and 9B through Rouses Point.
55.4	1.2	Route 11 turns westward, turn right and continue on Route 11.
58.9	3.5	Bridge over Great Chazy River. Continue westward on Route 11.
59.5	0.6	Intersection of Routes 9 and 11. Turn left onto Route 9 and proceed southward.
62.7	3.2	Intersection of Routes 9 and 9B and LaValley Road. Turn right and proceed westward on LaValley Road.
67.0	4.3	Cross Great Chazy River and continue westward on LaValley Road.
67.7	0.7	Intersection of LaValley and McBride roads. Turn left and proceed southward on McBride Road.
68.0	0.3	Cross Great Chazy River and continue southward on McBride Road.
69.1	1.1	McBride Road bears sharply eastward. Turn right onto George Duprey Road and proceed southward.
69.7	0.6	Intersection of George Duprey and Blair roads. Turn right onto Blair Road and proceed westward.
70.0	0.3	STOP #2. Champlain Sea beach ridges. Continue westward following the discussion at this stop.
70.3	0.3	Intersection of Blair Road and Route 22. Turn left onto Route 22 and proceed southward to Scioto.
71.7	1.4	Intersection of Routes 22 and 191 in Scioto. Turn left onto Route 191 and proceed eastward.
76.2	4.5	Intersection of Route 191 and Sand Ridge Road at the W.H. Miner Agricultural Institute. The Miner Institute is affliated with the Center for Earth and Environmental Science at P.S.U.C.
		Turn right onto Ridge Road and proceed southward. The road follows the crest of the Ingraham Esker. Note that in places gravel operations have removed nearly all the esker material except for that under the road.

CUM. MILES	MILES F.L.P.	DESCRIPTION
77.4	1.2	Lake Alice, named for Alice Miner. Continue southward on Ridge Road.
78.9	1.5	Intersection of Ridge and Clark roads. Turn left onto Clark and proceed eastward to Old Route 348.
79.0	0.1	Intersection of Clark Road and Old Route 348. Turn left onto Old Route 348 and proceed northeastward.
79.3	0.3	Intersection of Old Route 348 and Ashley Road. Turn right onto Ashley Road and proceed southward along the crest of the esker.
80.2	0.9	Cross the Little Chazy River and continue southward to the Slosson Road intersection.
80.3	0.1	Intersection of Ashley and Slosson roads. Turn left onto Slosson road and proceed eastward.
80.6	0.3	Cross the Little Chazy River and continue eastward to the Esker Road intersection.
80.7	0.1	Intersection of Slosson and Esker (Ridge Road on some maps) roads. Turn right and proceed southward on Esker Road. The road follows the crest of the esker.
80.8	0.1	Cross the Little Chazy River and continue southward.
82.2	1.4	STOP #3. Ingraham Esker. Continue southward to the Stratton Hill Road intersection following the discussions at this stop. The next stop will be at Point Au Roche State Park for lunch.
82.7	0.5	Intersection of Esker and Stratton Hill roads. Turn left and proceed eastward across I-87 overpass on Stratton Hill Road.
82.9	0.2	Intersection of Stratton Hill Road and an unmarked road. Turn right at the stop sign and proceed southward on Stratton Hill Road to the hamlet of Ingraham.
83.9	1.0	Intersection Stratton Hill Road and Route 9. Turn right and proceed southward on Route 9. The esker crosses the highway 0.3 mi south of this intersection.
86.0	2.1	Intersection of Route 9 and Point Au Roche Road. Turn left and proceed eastward on Point Au Roche Road.
87.6	1.6	Entrance to Point Au Roche State Park (beach and picnic area). Turn right into park for lunch.

CUM. MILES	MILES F.L.P.	DESCRIPTION
		After lunch proceed to entrance and turn left onto Point Au Roche Road.
89.2	1.6	Intersection of Point Au Roche Road and Route 9. Turn right onto Route 9 and proceed northward to blinking light at the Spellman Road intersection.
89.6	0.4	Intersection of Route 9 and Spellman Road. Turn right and proceed westward on Spellman Road.
90.1	0.5	Continue westward on Spellman Road across the I-87 overpass.
91.8	1.7	Continue westward across railroad crossing.
92.0	0.2	Intersection of Spellman and Ashley roads. Turn left and proceed southward on Ashley Road.
93.1	1.1	Cross Ray Brook and continue southward to Route 22 intersection.
93.3	0.2	STOP #4, Korths Farm Sections. Park along the side of the road near the cemetary at the intersection of Ashley Road and Route 22.
		Proceed southward on Route 22 following the discussions at this stop. For those who do not wish to continue to Stop 5 (Whallonsburg Slump-earthflow) follow the road log to the I-87 interchange in Plattsburgh.
96.1	2.8	Intersection of Routes 9 and 348. Turn left and proceed eastward to the I-87 interchange.
96.3	0.2	Entrance ramp for I-87 southbound. For those who wish to continue to Stop 5, turn right onto I-87 and proceed southward to Exit 33 south of Keeseville.
115.6	19.3	Exit 33. Turn right onto exit ramp.
115.9	0.3	Intersection of exit ramp and I-87 overpass. Turn left and proceed eastward across overpass.
116.0	0.1	Intersection of Routes 9 and 22 at traffic light. Procedd straight through the intersection and proceed southeastward on Route 22 to Willsboro.
124.2	8.2	Cross the Bouquet River at Willsboro and continue southward on Route 22 through town.

CUM. MILES	MILES F.L.P.	DESCRIPTION
124.6	0.4	Intersection of Route 22 and Middle Road. Turn sharply right onto Middle Road and proceed southward.
128.2	3.6	Intersection of Middle Road and Route 22. Turn right onto Route 22 and proceed westward on Route 22.
129.3	1.1	Route 22 curves sharply southward. Continue on Route 22 to Whallonsburg.
131.9	2.6	Cross Bouquet River and proceed to intersection of Cook Road (0.1 mi)
132.0	0.1	Intersection of Route 22 and Cook Road. Turn sharply onto Cook Road and proceed northward. The roadbed is composed of wollastonite tailings from nearby mines in Willsboro.
132.9	0.9	STOP #5, Whallonsburg slump-earthflow. Leave cars and follow the trail northward to the slump.
		Proceed southward on Cook Road to the intersection with Route 22 following the discussions at this stop.
133.8	0.9	Intersection of Cook Road and Route 22.
		For those with southbound destinations turn right and follow Route 22 southward to Route 9N in Westport. Form this point follow the signs to I-87.
		For those with northbound destinations turn left and follow Route 22 northward through Willsboro to its intersection with I-87 near Keeseville.
		END LOG