CAMBRIAN AND ORDOVICIAN PLATFORM SEDIMENTATION - SOUTHERN LAKE CHAMPLAIN VALLEY

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INTRODUCTION

The Cambrian-Medial Ordovician strata of the southern Lake Champlain Valley record the evolution and demise of passive margin sedimentation on the North American coast of the proto-Atlantic Ocean. The goals of our trip are to examine exposures of key units in this stratigraphy, interpret the depositional environments represented and consider the possible tectonic controls over the history of platform sedimentation during the early Paleozoic in eastern North America.

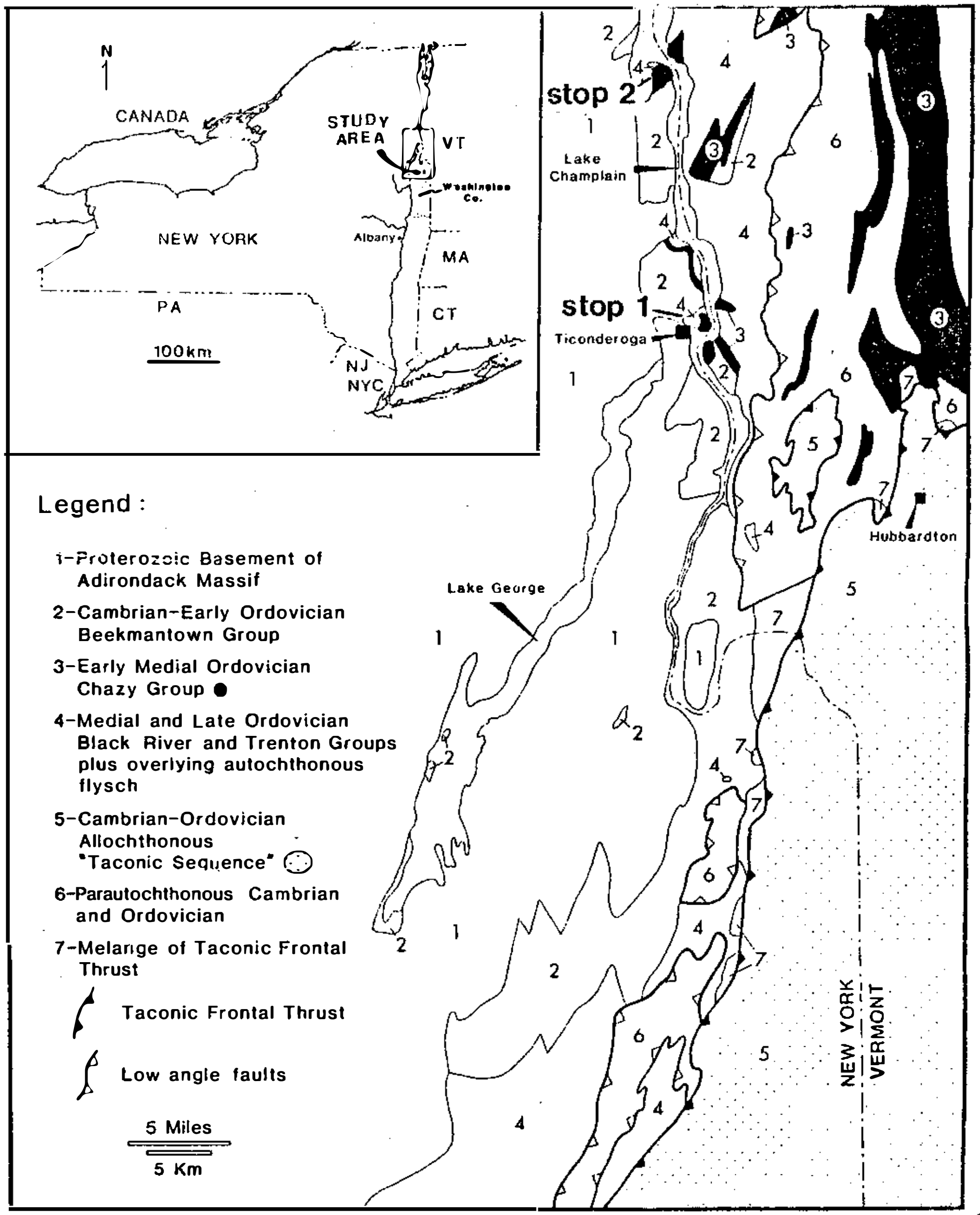
Our trip will focus on two sections of the stratigraphy: (1) the Late Cambrian Ticonderoga Dolostone and basal Whitehall Formation and (2) the Medial Ordovician Chazy, Black River and Trenton Groups. The general area of interest (Fig. 1) lies within the Ticonderoga and Port Henry, N.Y. 15' Quadrangles.

REGIONAL STRATIGRAPHIC FRAMEWORK

The stratigraphic column of Figure 1 illustrates the generalized thickness and lithologies of the strata which comprise the Cambrian and Ordovician of the southern Lake Champlain Valley. The availability of natural exposure in the region, the relative ease of access and the early settlement account for the long history of geological studies in the region. Early workers recognized that the Paleozoic ("Secondary") rock units in northern and eastern New York consisted of basal sandstones (Potsdam Sandstone of Emmons, 1842) overlain by mixed quartz sandstones and dolostones (Calciferous sandrock of Emmons, 1842 and Mather, 1843; later included in the Beekmantown Group by Clarke and Schuchert, 1899), followed by younger calcite limestone (Chazy of Emmons, 1842; Black River of Vanuxem, 1842 and Trenton Group of Conrad, 1837). The stratigraphy of Cambrian and Ordovician in New York has been recently updated by Fisher, 1977, whose usage we generally follow in this report.

Grenvillian Adirondack Basement:

The eastern Adirondack Highlands form the western margin of the Lake Champlain Valley. Granulite facies ortho- and paragneisses, marbles and metanorthosites bear metamorphic age dates of approximately 1.1 billion years (Weiner et al., 1984). Following the Grenville Orogeny, a period of approximately 500 million years of erosion ensued, resulting in the denudation of the ancestral Adirondacks to a relatively low relief topographic surface (Selleck, 1981).



AGE		GROUP	FORMATION	THICKNESS (METERS)
Ordovician			Canjoharie/Snake Hill	400+
Ordovician	Medial	Trenton	Glens Falls	20-50
Ordovician	Medial	Black River	Orwell	5-40
Ordovician	Medial	Chazy	Crown Point	10-55
Ordovician	Early	Beekmantown	Fort Cassin	10-90
Ordovician	Early	Beekmantown	Fort Ann	15-40
Ordovician	Early	Beekmantown	Great Meadows	20-70
Ordovician	Early	Beekmantown	Whitehall	20-110
Late Cambrian		Beekmantown	Ticonderoga	30-80
Late Cambrian		Beekmantown	Keeseville (Potsdam SS)	30-85
Late Cambrian			Ausable (Potsdam SS)	0-200
Proterozoic				

Figure 1. Generalized geology and lithostratigraphy - Southern Lake Champlain Valley

Basal Sandstones:

The basal Potsdam Sandstone in the region consists of two petrographically distinct facies. Sporadically distributed arkosic arenites and polymict conglomerates form the oldest post-Grenvillian sedimentary rocks in the region. These basal facies are similar to the Ausable Member (Fisher, 1968) of the Potsdam Sandstone in the northern Lake Champlain Valley and comprise a suite of immature terrigenous clastics that were deposited on a relatively uneven topographic surface prior to the onset of Cambrian marine deposition. This "Ausable Sandstone Suite" is thought to represent non-marine deposition in normal fault-bounded basins of small areal extent that developed in response to the uplift and extension of eastern North America during the initiation of rifting of the Proto-Atlantic margin in late Proterozoic-early Cambrian time (Fisher, 1977). The lack of fossils or datable minerals hinders age determinations of these facies. Common themes are the abundance of little-reworked, locally-derived detritus and braided stream/alluvial fan depositional environments. In the southern Lake Champlain Valley, arkosic sandstones and conglomerates of the "Ausable Suite" are exposed in roadcuts on N.Y.S. Rt. 22 near Putnam Center, N.Y.

The Keeseville Member of the Potsdam Sandstone (Fisher, 1968) is an areally extensive, compositionally mature quartz sandstone that overlies both the Ausable Facies clastics, where present, and Grenvillian Basement. In the Southern Lake Champlain Valley the Keeseville is Late Cambrian (Dresbachian) in age and apparently consists largely of shallow marine facies, although detailed investigation of this unit is lacking. Numerous exposures of the Keeseville occur near Putnam Center, N.Y. between Rt. 22 and the west shore of Lake Champlain. Fisher (1977) abandoned previous usage by including the Potsdam Sandstone within the Beekmantown Group.

Beekmantown Group

The transition from siliciclastic to carbonate-dominated deposition occurs within the Ticonderoga Dolostone (Late Cambrian-Franconian) of the Beekmantown Group. The Ticonderoga consist of rhythmically interbedded cross-stratified quartz sandstones and burrowed dolomitic sandstones. This facies is similar to the Theresa Formation which overlies the Keeseville Member of the Potsdam elsewhere in northern New York. The Ticonderoga Dolostone is interpreted as a peritidal deposit, with the cross-stratified facies of low intertidal to shallow subtidal origin and the burrowed facies of higher tidal flat origin (Caplow et al., 1982).

The overlying Whitehall Formation contains the Cambrian-Ordovician boundary (Fisher, 1977, 1984). Relatively pure dolostones, limestones, cherty dolostones and algal boundstone structures characterize the Whitehall and a variety of tidal flat and subtidal carbonate environments are represented

(Rubin, 1975; Rubin and Friedman, 1977). An arid climate coastal setting for the Whitehall is indicated by halite crystal casts and early silicification (Rubin and Friedman, 1977). Exposures of the Ticonderoga Dolostone and Whitehall Formation are numerous in the vicinity of Ticonderoga village.

The younger formations of the Beekmantown Group (Great Meadows, Fort Ann, Fort Cassin/Providence Island Dolostone) are well-exposed in the Whitehall-Glens Falls region. In general, these units consist of dolostones and dolomitic limestones of shallow marine/peritidal origin (Fisher and Mazzullo, 1976; Mazzullo, 1974; Fisher, 1984).

The Beekmantown Group is part of an extensive Cambrian-Medial Ordovician carbonate suite which parallels the early Paleozoic continental margin from Quebec to Alabama and extends west to the mid-continent. Within the Beekmantown Group some recurring themes are evident:

(1) Tidal (astronomical or storm-related?) depositional processes;

(2) General facies arrangement consisting of basal quartz sandstone overlain by carbonates (generally dolostones);

(3) Quartz sandstones more common to west (closer to cratonic interior) with contemporaneous carbonate deposition to east;

(4) Shifts of sandstone and carbonate facies belts onto more outboard shelf positions during sea-level fall; shifts inboard (toward cratonic interior) during sea level rise;

(5) Very limited faunal diversity in sandstone and dolostone facies;

(6) Features suggesting an arid climate coastal setting;

(7) Lack of fluvial or deltaic facies (except in basal "Ausable Suite"); probable input of terrigenous sand by aeolian transport to marine system;

(8) Limited terrigenous mud.

The Beekmantown Group records the post-rift, passive margin phase of sedimentation on the Proto-Atlantic margin of North America. Beekmantown deposition ended in late early Ordovician time with a period of emergence of the platform. Erosion of Beekmantown strata extended from the continental interior to the platform margins. Normal faulting of the shelf may have occurred at this time, as well. The unconformity produced during this erosional interval (the "Knox", or "Sauk" unconformity) may document a change in the plate margin from a phase of extension and subsidence to a more dynamic phase. Some workers (e.g., Bird and Dewey, 1971; Rowley and Kidd, 1982) have speculated that this uplift/erosional interval may be due to the development of a forearc bulge on the continental margin immediately prior to the Taconic Orogeny. Continuous deposition over this otherwise erosional interval may have occurred on the more seaward portions of the shelf, and in those more landward areas that underwent relatively continuous subsidence (including perhaps, the northern Champlain Valley; Speyer, 1982).

Chazy Group

The stratigraphy of the Chazy Group has been investigated most recently by Oxley and Kay (1959) and Hoffman (1963). Fisher (1968) provides descriptions of Chazy strata in the northern Lake Champlain Valley. The Chazy strata of the southern Lake Champlain Valley have generally been assigned to a single formation, the Crown Point (Oxley and Kay, 1959).

The Chazy Group marks the resumption of shallow marine deposition following the post-Beekmantown erosional interval and it is clear that the platform was considerably changed in terms of climate and tectonic regime. The Chazy Group in New York, Vermont, Quebec, and Ontario is characterized by rapid lateral and vertical facies changes, and considerable local and regional thickness variation. Chazy Group strata total 235 meters (800 feet) thickness in the northern Lake Champlain Valley (Fisher, 1968) but thin rapidly to the south, and are absent from the platform stratigraphy in New York south of Whitehall. Chazy Group rocks are present beneath the Taconic thrust sheets to the south and east of Whitehall, based upon the presence of allochthonous faults slivers of Crown Point strata at the base of the Taconic Frontal Thrust (Selleck and Bosworth, 1985).

Rapid facies changes occur along the Champlain Valley outcrop belt, apparently in response to local development of shoalwater barriers and reefs on topographic highs (Fisher, 1968). Tidal flat, shelf lagoon, shoal sands, reef and reef flank facies are exposed in the Champlain Valley. Siliciclastic lithologies are locally present in the basal units and dominate in the Ottawa Valley region, where non-marine (braided stream?) facies are present (Hoffman, 1963).

In the southern Lake Champlain Valley, reef facies are absent from the Chazy, but faunal diversity is high, much in contrast to the poorly fossiliferous Beekmantown Group. Brachiopods, algae, bryozoans, gastropods, nautiloids, trilobites, and pelmatozoans are abundant in subtidal shelf lagoon facies. The occurrence of microkarst erosional surfaces and the absence of evaporitic indicators in tidal flat facies, plus the overall high faunal diversity can be linked to a relatively humid climate during Chazy Group deposition (Selleck, 1983).

A regional disconformity caps the Chazy Group in the southern Lake Champlain Valley, suggesting slight emergence of the shelf prior to deposition of the Black River Group. In places (e.g.

Crown Point) this discontinuity is marked by a thin (approx. 1 meter) arkosic sandstone.

Black River Group

In the type area of the Black River Group in northwestern New York State, four formations are recognized; the Pamelia, Lowville, Chaumont and Watertown. Although facies resembling portions of these formations are present in the Black River Group in the southern Lake Champlain Valley, the Group is considerably thinner here than in the type area and a single formation name, the Orwell, is generally applied. Fisher (1984) suggests that the Isle La Motte and Amsterdam Formations are present in the Glens Falls-Whitehall Region, to the south of our area of concern. In general, the basal Black River Group strata consist of quartz sandy dolostones immediately overlain by poorly fossiliferous dolostones and lime mudstones. These facies are rapidly replaced upsection by bioturbated, fossiliferous (gastropods, cephalopods, rugose and tabulate corals, brachiopods, crinoids, stromatoporoids, bryozoa) packstones and wackestones which characterize the Orwell in most exposures. This increase in faunal diversity reflects environmental change from muddy tidal flats (basal Orwell) to a more offshore, relatively low energy, subtidal carbonate shelf setting.

Trenton Group

In the southern Lake Champlain Valley, the contact between the Black River and Trenton Groups is somewhat gradational and characterized by increasing terrigenous mud content. Previous workers have placed the Trenton-Black River contact within the Orwell Limestone, based upon faunal correlations with the type Black River and Trenton. We have followed this rather peculiar usage in this report, but suggest that the natural lithostratigraphic boundary between the Black River and Trenton could be placed at the summit of the massive packstones of the Orwell (= Isle LaMotte). Further study is needed on this problematic contact. Trenton limestone beds are often subtly graded and current lamination is common. Mehrtens (1984) has suggested that similar Trenton Group facies are turbidites and their presence indicates increased local slopes on the Trenton carbonate shelf. Faunal diversity in the Glens Falls limestone is quite high, and the faunas are typically dominated by brachiopods, bryozoans, trilobites, nautiloids and crinoids. Mud-intolerant corals and stromatoporoids are notably uncommon in the Trenton Group.

Canajoharie/Snake Hill

The transition from the Trenton Group limestones to overlying dark mudrocks of the Canajoharie Shale (=Snake Hill of Fisher, 1977) is clearly the result of continued deepening of the Trenton shelf to depths sufficient to reduce biogenic carbonate production, coupled with increased input of terrigenous mud. The organic-rich character of these dark shales and siltstones indicates poor oxygenation of the bottom waters. The change from carbonate to black mud deposition occurred earlier in the Champlain Valley than in the western Mohawk Valley and Black River Valley/Tug Hill Region (Fisher, 1977). This progressive east-to-west deepening of the foreland basin was initially due to the wedging of the continental margin into the subduction zone. This convergent-margin tectonism (Baldwin, 1980, 1982) is reflected in the Timor Trench today where shallow-water mid-Pliocene limestones are now 2.7 km deep. Soon after, subsidence also reflected the loading of the continental margin by west-directed compression and thrusting of "Taconic Sequence" Cambrian-Early Medial Ordovician rise prism sediments onto the edge of the carbonate platform (Rowley and Kidd, 1981). Cisne et al. (1982) have suggested that the convergent tectonic regime of the Taconic Orogeny and related history of the Medial Ordovician Foreland basin in the Mohawk Valley is analogous to the modern Timor-Timor Trough-North Australia Shelf collisional system. In the Timor analogue, the attempted underthrusting of the northern Australian plate margin has led to progressive deepening and syndepositional normal faulting of the previously shallow water North Australia platform, producing a "deep-over-shallow" facies pattern that is very similar to the Canajoharie Black Shale-over-Trenton Limestone sequence of the Medial Ordovician in New York State. Baldwin (1980) has documented the history of Ordovician shelf subsidence and accompanying changes in depositional rates in the Champlain Valley.

Following the deposition of Canajoharie-Snake Hill black muds on the foundered carbonate platform, synorogenic flysch developed as aprons of sediment that were shed from the rising Taconic accretionary prism. In some areas, these deposits are deformed and overthrust by later thrust sheets. Molasse deposition is recorded in deltaic and marine shelf facies of the Late Ordovician Lorraine Group and Oswego Sandstones in northwestern New York. These deposits do not occur in the Southern Lake Champlain Valley.

Post-Ordovician:

The post-medial Ordovician geologic history of the region is not recorded in local sedimentary sequences and is hence rather difficult to interpret. The pronounced normal faults which form the physiographic boundary between the Champlain Valley and the Adirondack Highlands are clearly post-Ordovician in age (Fisher, 1968) and may be as young as Tertiary (Isachsen et al., 1976). Glacial erosion and deposition, including a late Pleistocene marine invasion in the Lake Champlain Valley, have caused significant modification of landforms in the region. The neotectonics of the region are characterized by minor earthquake activity and possible on-going uplift of the Adirondack massif (Isachsen, et al., 1978).

Field Trip Stop Descriptions:

As this trip involves only two "stops" we have not included a road log. To reach Stop #1 from Saratoga Springs, take Interstate 87 north to the Route 73 exit (Schroon Lake) and proceed east to Ticonderoga. At the Rt. 9N and 22 intersection with Route 73, proceed east, then south (1 1/2 miles) on Rt. 22 to Shore Airport Road. Turn left on Shore Airport Road. Stop #1A is the first of a series of outcrops on Shore Airport Road approximately 0.3 miles from Rt. 22 intersection.

From Stop #1, proceed east, then north on Shore Airport Road to intersection with Rts. 9N and 22. Turn right (north) and follow 9N and 22 through village of Crown Point. Turn right (east) onto Route 8 to Crown Point Reservation State Park Bridge to Vermont and Campground. Proceed east approximately 4 miles to entrance to State Historic Site.

STOP #1 - Shore Airport Road Outcrops - Ticonderoga Village

Relatively new roadcuts on Shore Airport Road provide excellent exposures of portions of the Ticonderoga Dolostone and Whitehall Formation. The generalized stratigraphy of this series of outcrops is presented on the following pages. Stop 1A is wholly within the Ticonderoga Dolostone; 1B is uppermost Ticonderoga Dolostone or basal Whitehall (Finch Dolostone of Fisher, 1984) Formation; Stop 1C is clearly Whitehall Formation, Finch Dolostone Member. We will walk upsection from the base of Stop 1A to Stop 1B, reboard the bus to Stop 1C. Please watch for cars!

Stop 1A - Ticonderoga Dolostone:

A series of normal faults juxtapose blocks containing various sections of the Cambro-Ordovician stratigraphy in the Ticonderoga area. To our southwest, Proterozoic marbles and gneiss hold up Prospect Mountain. The village of Ticonderoga largely sits upon Potsdam Sandstone (Keeseville Member). To our south and east, the younger formations of the Beekmantown Group are exposed in the vicinity of Fort Ticonderoga. At this stop approximately 20 meters of Ticonderoga Dolostone is exposed. The basal 2/3 of the outcrop consists of 0.2 - 1.0 meter units of bioturbated sandy dolostone interbedded with 0.1-1.0 meter units of cross-stratified slightly dolomitic medium to fine sandstones. Rare prism cracks in the fine silty dolostones document sporadic subaerial exposure. "Herringbone" cross-strata, reactivation surfaces and shear-deformed cross-strata are well-exposed on weathered surfaces of the sandstones. Poorly preserved specimens of the gastropod *Ophileta* sp. are found on the bedding surface of a dolomitic sandstone approx. 8 meters from the base of the section. R. Linsley (personal communication) has suggested that *Ophileta* was a relatively sedentary grazer or deposit feeder. The upper 1/3 of the section contains relatively more abundant prism cracks, shaly interbeds and intraclast breccia horizons, perhaps indicating more regular subaerial exposure.

The rhythmically interbedded bioturbated dolostones and cross-stratified dolomitic sandstones are interpreted as high and low tidal flat/shallow subtidal facies, respectively. Carbonate mud and terrigenous sands deposited on a relatively low energy upper intertidal flat provided a suitable habitat for burrowing infaunal organisms. The lower tidal flat and shallow subtidal environment was characterized by more vigorous current action which limited faunal activity and produced cross-strata and associated structures. The repetitive interbedding of these facies suggests repetitive progradation of burrowed sandy muds over current-bedded sands. The upsection decrease in current-produced structures and increasing evidence of exposure indicates an overall shallowing up trend in the Ticonderoga Dolostone at this locality.

<u>Stop 1B - Outcrop on north side of Shore Airport Road approx. 150 meters east of Stop #1A</u>

This outcrop exposes about 7 m of silty, cherty dolostones assignable to either the uppermost Ticonderoga Dolostone or the basal Finch Member of the Whitehall Formation. The pervasive dolomitization plus outcrop weathering have obscured the primary structures and fabrics. The lower approx. 1 meter consists of laminated silty dolostones with ripple cross-lamination and thin intraclastic horizons. The succeeding 1.5 meters consists of thick-bedded to massive coarsely crystalline dolostone containing calcite-filled voids of various sizes. The succeeding 2 meters consists of bioturbated, dark medium crystalline dolostone with vaguely developed digitate algal (?) structures. Laminated, finely crystalline dolostones follow, capped by dolostones with algal mounds. In the upper 1 1/2 m of the outcrop, cherty, laminated dolostones apparently drape an irregular algal mound (thrombolites) surface. Note laminated silty dolostone between algal mounds.

The lack of diagnostic fossils and primary structures in these lithologies make environmental assignment difficult. If the digitate algal structures and cryptalgal laminites are indeed present, a shallow subtidal to low intertidal environment may be inferred. Bioturbated dolostones could be of intertidal or more offshore origin. Any suggestions?? (We will reboard bus at this point and continue east on Shore Airport Road 400 meters to Stop 1C.)

<u>Stop 1C (outcrop on north side of road)</u>

Approximately 3 1/2 meters of the Finch Dolostone Member of the Whitehall Formation is exposed at this stop. Three facies occur in a somewhat repetitive fashion: (A) Coarsely crystalline, laminated to slightly bioturbated dolostone (dolomitized grainstone); (B) "pin-stripe" laminated cherty finely crystalline dolostone with rare burrows; and (C) dark grey to black dolomitic chert with dolomitized molluscan debris and dolomitic digitate algal stromatolites and dolomite "knots" (small algal structures??). The uppermost dolomitic chert bed thickens and thins on outcrop scale. The thicker portions of this bed appears to represent local "domes" or mounds formed by the thrombolites or algal stromatolites. Gastropod debris can be seen in one mound, perhaps representing shell material collected between cylindrical algal pillars.

The absence of direct evidence of subaerial exposure again makes exact environmental assignment quite equivocal. We suggest that the coarsely crystalline dolostones represent a "high energy" shallow subtidal/low intertidal facies; the "pin stripe" laminites a relatively lower energy muddy tidal flat facies. The dolomitic chert facies containing algal structures is probably shallow subtidal. We are again open to suggestions.

The origin of the silica for chertification of these rocks is also something of a problem. Rubin (1975) suggested that subaerial "silcretization" involving dissolution of terrigenous silicates and precipitation of opaline silica or quartz in a pedogenic setting on emergent tidal flats was a factor in chertification of Whitehall Formation carbonates. The fabrics indicating pedogenic silicification reported by Rubin are not present at this locality, however. A possible alternative is fabric-selective replacement of primary carbonate mud by silica derived from a biogenic source (sponge spicules) within the original sediment.

Route to Stop #2

Reboard bus, continue east, then north on Shore Airport Road to Rts. 9N and 22. Outcrops of the Whitehall Formation and Great Meadows Formation are seen as we continue on Shore Airport Road. North on Rts. 9N and 22, through village of Crown Point, turn right at sign for Crown Point (N.Y. Rt. 8) Historic Site and Bridge to Vermont. Continue NE to Crown Point Historic Site. Entrance on left. We will disembark by the entrance to the Historic Site. Stop #2A is in the ditch and wall of a small outpost fort on east side of N.Y. Rt. 8. Stop 2 locations are keyed to the map and columnar section on the next two pages. Note: Absolutely no hammering or collecting at the Crown Point outcrops!

STOP #2A: Outpost fort east of N.Y. 8

Approximately 6 meters of variously burrowed, slightly dolomitic, thin to medium bedded bioclastic packstones are exposed in this section. The dolomite occurs in shaly weathering wisps and laminae and in burrow fills. Abundant "Girvanella" algal oncolites (algal accretionary grains) are present in beds approx. 4 meters from the base of the section. Rounded dark calcite grains (abraded gastropod fragments) form the cores of the oncolites, and are scattered in other beds. Fossils are relatively abundant and best seen on bedding surfaces. Trilobite fragments, brachiopods, bryozoans, pelmatozoan plates, nautiloids and large Maclurites magnus are present. The relatively high faunal diversity, abundant lime mud and burrowing argue for a normal marine, low energy shallow subtidal carbonate environment. A possible modern analogue is found in the mixed mud and sand shelf to the west of the emergent Andros Island tidal flats, as described by Bathurst (1971) and Purdy (1963). The 5-10 cm thick beds of "oncolite conglomerate" and other more well-sorted grainstone beds may represent periods of storm winnowing of the bottom, with transportation of abraded sand from adjacent sand shoal environments (e.g. Locality 2B). The wavy, irregular dolomite laminae appear to result from post-depositional dolomitization of lime mud, followed by compaction and local pressure solution of calcite, producing irregular, clay- and dolomite-rich stylocumulate seams. Preferential dolomitization of burrows may be due to contrasts in porosity or permeability of burrow-fill versus burrow-matrix sediment. The burrow-fill sediment may have retained permeability longer during diagenesis, permitting pervasive dolomitization. This sort of fabric selective dolomitization is common throughout the Chazy and Black River Groups in the southern Lake Champlain Valley.

STOP 2B - Ledge immediately NE of gate to Historic Site

Cross-stratified coarse lime grainstones with bipolar crossbed dip directions are well-exposed near the entrance road. Siliciclastic sand grains (angular quartz and feldspar up to 2 mm in diameter) are locally concentrated along prominent stylolite seams. The carbonate particles are dominately subrounded, abraded pelmatozoan plates, plus gastropod and brachiopod fragments. Large Maclurites fragments and grainstone intraclasts are present on the upper bedding plane surfaces of the ledge.

We envision the environment of deposition of this facies as shallow subtidal wave and/or current reworked sand bars. Active transport of abraded grains may have been accomplished by tidal currents as suggested by the bipolar cross-beds. The lack of burrows and well-preserved fossils may be due to the inhospitable shiftng sand substrate. This environment may have been rather like the unstable sand shoal environments described from the Bahamas Platform by Bathurst (1971) and Ball (1967). The scale and style of cross-stratification present here are similar to that predicted by Ball from his studies of the bedforms and primary structures of the Bahamian sand bodies. Similar Chazyan facies in the Northern Champlain Valley contain abundant oolites (Oxley and Kay, 1959).

STOP 2C - Low Ledges on entrance road approx. 50 meters north of 2B

Brown weathering, slightly shaley dolostone exposed here contains small lenses and stringers of fossiliferous lime packestone. Trilobites, small brachiopods and Maclurites fragments are common. This exposure resembles the shelf lagoon facies of Stop 2A, although dolomitization is more pervasive.

STOP 2D - East point of British Fort, by horizontal water tank and adjacent south moat

Approximately 3 meters of thickly laminated limestone and dolostone is exposed in the southeast "moat" of the British Fort. The dominant facies here consists of alternating 0.5-2 cm thick laminae of limestone and dolostone - often termed a "ribbon rock". The limestone ribbons are mudstones and appear blue-grey on slightly weathered surfaces and as indentations on highly weathered surfaces. The more resistant dolostone weathers tan to brown. An erosional surface with 10-20 cm of relief is exposed near the base of the southwall. Abundant Maclurites shells occur in a shell bed on this surface. Lateral accretion cross-strata consisting of gently dipping ribbon rock are present above the erosional surface. Dolomitized burrows transect the limestone ribbons in the lower 1 meter of the section. On the less-weathered prominence on the SE corner of the moat, shallow scours containing a shell hash of brachiopods and gastropod debris are present, along with intraclasts of lime mudstone in dolostone and "Mexican Hat" structures (rolled intraclasts or pseudoclasts with a dolomitized burrow center).

We interpret this sequence as a tidal flat facies. The rhythmic limestone/dolostone "ribbon" fabric is interpreted as representing alternating slightly finer (lime mudstone) and coarser (dolostone) "tidal bedding" similar to that described by Reineck and Singh (1980) from the clastic mud/sand tidal flats of the North Sea. The Maclurites shell bed may mark the basal erosional level of a tidal channel, with the cross-stratified ribbon laminites forming by draping on the channelled surface. Variations in degree of burrowing record subtle differences in degree of subaerial exposure of the flat and/or reworking by tidal currents. Limited in situ faunal diversity is also expected in the stressed tidal flat environments. The absence of mudcracks and any indication of evaporite minerals suggests that we are seeing only the lower portion of a wet intertidal flat system preserved here.

STOP 2E

Enter Parade Grounds by barracks. Around 1916, gunite was spayed on the interior walls to protect the mortar from deteriorating. Starting in 1976, the N.Y. State Division for Historic Preservation began extensive maintenance, removing loose gunite, replacing rotted stones and repainting the stone walls.

In the outer wall of the first barracks, note at about eye level the stones that are nearly white-weathering. These are lime mudstones from the "Lowville" facies of the Orwell Limestone, exposed at Stop 2F.

The broad limestone outcrop west of the barracks is a cross-stratified lime grainstone with scattered subrounded quartz and feldspar sand grains. Trough cross-strata and "herringbone" co-sets of planar-tabular cross-strata are visible on the low vertical face. Large angular clasts of slightly dolomitic lime grainstones and Maclurites magnus shells are present on the uppermost bedding surfaces.

We interpret this facies as a current-dominated sand shoal environment rather similar to the exposures at Stop 2B.

Westward across the parade grounds there is a massive, bioturbated, brown weathering dolostone unit (similar to Stop 2C), overlain by 0.5 meters of very coarse-grained bioturbated, slightly dolomitic feldspathic quartz sandstone. This sandstone forms the summit of the Chazy Group (Crown Point Formation). The abundant angular quartz and feldspar granules in the sandstone suggest derivation from a relatively close granitic (Adirondack?) source terrane. These sands were apparently transported from the west during an interval of relative emergence of the carbonate platform and were briefly reworked in a shallow marine setting. The basal dolostone bed of the Black River is exposed immediately atop the sandstone.

STOP 2F - Moat Walls at North Entrance to British Fort

The section from here to locality I is within the Orwell Limestone. The basal beds consists of thick-bedded to massive lime mudstones with vertical spar-filled burrows (form - genus Phytopsis) and rare ostracodes. Fossil abundance and diversity increase in the overlying beds, with gastropods (Loxoplocus), corals (Lambeophyllum, Foerstephyllum) and brachiopods appearing. Grain size increases upsection, with sporadic appearance of intraclast grainstones and ripple cross-lamination. Overall this section is similar to the Lowville Limestone of the type Black River Group of the Tug Hill region. The facies pattern here suggests a progression from restricted (tidal or lagoonal?) mud flats (Phytopsis lime mudstones) to more open marine mixed mud/sand shelf environments.

The summit of the moat outcrop exposes a horizon of black chert nodules which can be traced laterally across the road to locality G.

Stop 2G - Ledges extending from service road to lake shore.
Watch for poison ivy!

These exposures closely resemble the Chaumont (House Creek Limestone of Fisher, 1977) facies of the Black River type section.

Thick-bedded to massive richly fossiliferous lime packstones and wackestones document a normal marine, relatively low energy carbonate shelf environment. In addition to the forms mentioned earlier, the large stromatoporoid (calcisponge) Stromatocerium, the high-spired gastropods Hormotoma and Subulites, the nautiloids Actinoceras and Geisonoceras, plus bryozoans, brachiopods and pelmatozoan material are common. On some bedding surfaces, black chert nodules follow large horizontal burrows. The chertification here is post-depositional and involved dissolution and reprecipitation of siliceous skeletal material (sponge and radiolarian). The uppermost bed in this set of ledges is a black chert bed approximately 2 cms thick. This bed can be traced to the lake shore where a similar section can be seen. Glacial abrasion obscures much of the detail that is exposed on more weathered surfaces.

STOP 2H - Blocks and Quarry Walls by Lake Shore

The quarry was established in 1870 by the Fletcher Marble Co. in a unsuccessful attempt to find a source of "black marble" dimension stone. The quarry is reportedly only 1 meter or so deep. The narrow spit going north was built to load blocks on barges, but evidently no blocks were shipped. The quarried blocks consist of medium to thick-bedded fossiliferous packstones and wackestones with some ripple cross-laminated grainstone beds visible in the north quarry bench. Strophomenid brachiopods, bryozoans, pelmatozoan stems and fragments of the trilobite Isotelus are present. The environments represented here are similar to those at 2G. As we continue north and walk along the lake shore, more exposures of the upper part of the Orwell can be examined. The bedding surfaces contain abundant opercula of Maclurites logani, and scattered Forstephyllum, Lambeophyllum and Stromatocerium are found. The byssate bivalve Ambonychia is also present.

The transition from the Orwell to overlying Glens Falls Limestone is covered by beach gravels as we continue west along the lake shore.

STOPS 2I,J,K - Series of exposures of Glens Falls Limestone separated by covered intervals of beach gravels

The westernmost outcrops are on Private Property, beyond Locality K. Do not go onto that part of the shore (marked by fence and stone wall, plus the large dead elm tree).

The Glens Falls limestone consists of medium to thin-bedded lime packstones and wackestones with some well-laminated, fine-grained bioclastic grainstones. Many limestone beds show internal grading from coarse, fossil-rich bases to less fossiliferous, fine-grained tops. Thin shaley interbeds separate the limestone beds. Horizontal trails and burrows (including form-genus Chondrites) are common on some bedding surfaces.

Fossils are abundant and rather diverse. Trilobites (usually fragmental) include Isotelus, Flexicalymene and rare Cryptolithus; the brachiopods Sowerbyella, Rafinesquina; Dinorthis and Dalmanella; bryozoans Prasopora, Eridotrypa and Stictopora; plus orthocone cephalopods and pelmatozoan debris. Gastropods, which are so abundant in the underlying Orwell limestone are exceedingly rare in the Glens Falls.

The environment of deposition for the Glens Falls is a sub-wave base shelf. No shallow water features are observed and the graded limestone beds are evidently deposited by density/turbidity currents generated on adjacent, slightly shallower portions of the shelf. The Glens Falls here records the continuing deepening of the Middle Ordovician shelf that began with the deposition of the Phytopsis lime mudstones at Stop 2F. The shale interbeds and generally more argillaceous character of the Glens Falls document increase in terrigenous mud input, perhaps derived from the rising Taconic Orogenic complex to the east. Quartz and feldspar grains of volcanic origin are also common in insoluble residues of Glens Falls limestones, suggesting increased eruptive activity at this time.

The contrast in terrigenous content of the Chazy Group vs. Black River and Trenton Groups is noteworthy. Insoluble residues from Chazy Group carbonates contain abundant, coarse-grained, rather angular quartz and feldspar grains (e.g. Stops 2B and 2D) plus clay-size material whereas the Black River and Trenton Groups lack coarse sand-size grains and contain either volcanic quartz and feldspar (Black River and Trenton Groups) or clay plus volcanics (Trenton Group). This change is likely related to a shift in available clastic source from the slightly emergent cratonic basement to the west that was exposed during Chazy Group deposition to the rising Taconic volcanic/metamorphic complex to the east during Black River-Trenton Deposition.

Tectonic Significance of the Crown Point Section

Combining the environments of deposition with the time-thickness pattern of sedimentation, the Crown Point section takes on tectonic meaning. The Chazy sediments were deposited just about at sea level -- Girvanella and Maclurites. The Orwell was deposited in shallow sub-tidal conditions -- two corals, the grazing snail Maclurites, and probably the Stromatocerium. The Glens Falls was deposited in a more offshore setting.

A time-thickness graph for the Cambrian-Ordovician sequence of the Champlain Lowlands shows some interesting changes in slope. Sedimentation through the Chazy yields a concave-upward curve that shows a continued slowing of crustal subsidence. Then, starting with the Orwell, the crustal subsidence is greater than the rate of sedimentation, because the water deepens. Using the Middle Ordovician time scale of Churkin and others (1977), it is clear that Chazy sedimentation was scarcely 5 m/m.y.; the Orwell and Glens Falls accumulated at 30 or 40 m/m.y., and the thick shales accumulated at 200 m/m.y. (solid-grain thickness). This high rate is comparable to the rate of subsidence of the Australian platform entering the Timor trench (600 m/m.y.; Baldwin, 1982).

The Crown Point section, then, fits the picture of a cooling and slowly subsiding continental margin, through Chazy time. Then, the margin began collapsing as it tried to enter a subduction zone to the east, causing water to deepen rapidly. The section is a record of the very early part of the Taconic Orogeny, as the "east-moving proto-North American Plate 'felt' the presence of an approaching island arc" (Baldwin, 1982). collision that constitutes the Taconic orogeny.

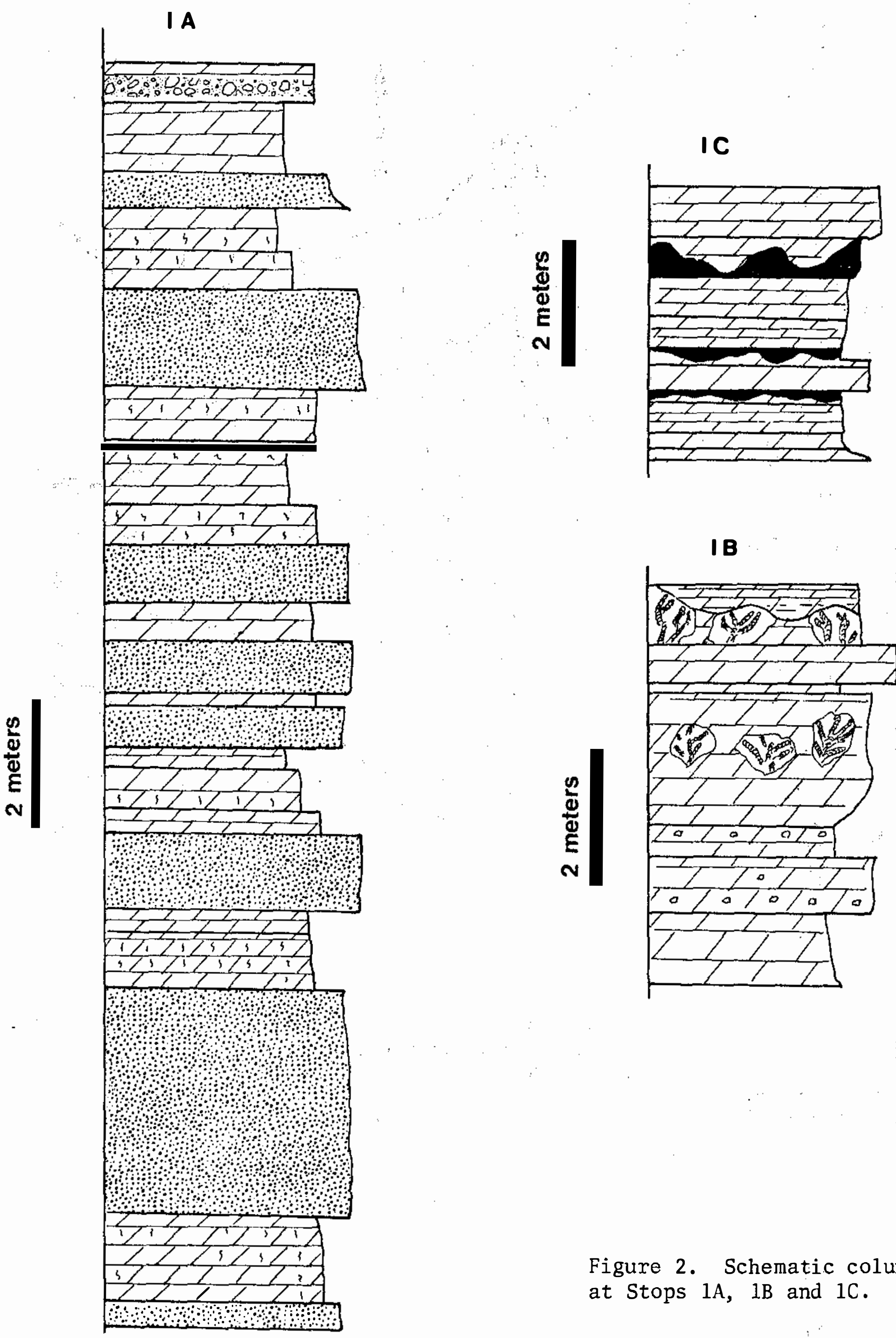
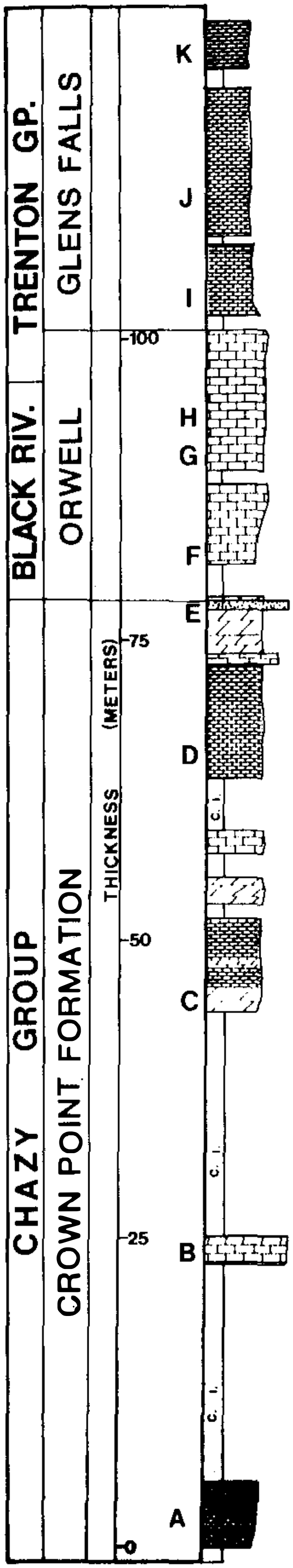


Figure 2. Schematic columnar sections at Stops 1A, 1B and 1C.



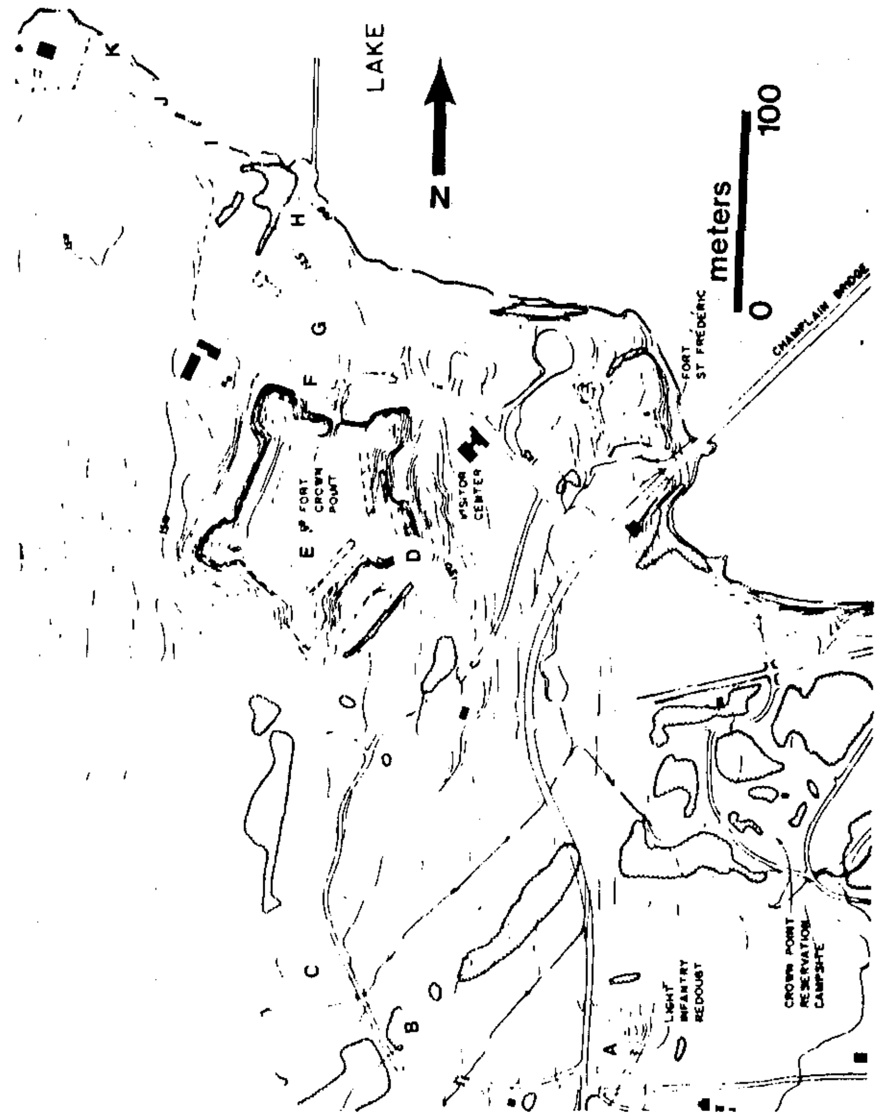


Figure 3. Composite columnar section and location map for Crown Point localities. Note that strata dip approx. 8°N35°W.

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