STRATIGRAPHY, SEDIMENTOLOGY AND DIAGENESIS OF THE POTSDAM FORMATION, SOUTHERN LAKE CHAMPLAIN VALLEY, NEW YORK

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INTRODUCTION

The Cambrian Potsdam Formation is widely exposed on the periphery of the Adirondack massif in northern New York State and adjacent Ontario and Quebec. As the basal unit of the Paleozoic sequence over the cratonic interior of eastern Laurentia, its distribution and character are strongly controlled by the geometery of the pre-Potsdam erosional surface, and patterns of rift-related faulting of the Iapetean margin and sea-level change. In the northern Lake Champlain Valley, the Potsdam is characterized by a basal arkosic unit, the Ausable Member, which is overlain by marine quartz sandstones of the Keeseville Member (Fisher, 1977) Recent study of key exposures in the Lake Champlain Valley region (Landing, 2007) have more firmly established age relationships of the Keeseville and Ausable Members of the Potsdam. Landing (2007) has also documented the existence of a Middle Cambrian unit, the “Altona” Formation, which underlies the Ausable Member of the Potsdam Formation in the northern Lake Champlain region.

The Potsdam Formation is approximately time-equivalent to the Danby and Winooski Formation of western Vermont (Mehrtens and Butler, 1987; Landing, 2007). The Potsdam is thickest in the northern Champlain Valley and adjacent southern Quebec (~250 meters), likely related to accumulation on the downthrown side of an Iapetan margin fault (Landing, 2007). In the area of this field trip, the total thickness reaches a maximum of 80 meters. A locally-developed basal arkosic unit may be correlative to the Ausable Member. The succeeding quartz-rich sandstones are referable to the Keeseville Member.

The Potsdam Formation acted as an aquifer for the transport of basinal brines and hydrothermal diagenetic fluids during burial. Significant diagenetic alteration of the original sediment has occurred, and the Proterozoic basement rocks beneath the Potsdam have been altered by hydrothermal fluids (Whitney and Davin, 1987). This alteration may be related to seismic pumping of fluids during Taconic (Late Ordovician), Acadian (Middle-Late Devonian) and/or Alleghanian (Carboniferous-Permian) tectonism on the Laurentian margin.

In the southern Lake Champlain Valley and Lake George Valley, the Potsdam records non-marine, tidal flat and nearshore marine depositional systems. This field trip will include exposures of a variety of sedimentary facies within the Potsdam Fomration, and will also examine relationships with underlying Proterozoic basement and burial diagenetic and hydrothermal features within the sandstone and basement rock.

STRATIGRAPHY AND SEDIMENTOLOGY OF THE POTSDAM FORMATION IN THE SOUTHERN LAKE CHAMPLAIN VALLEY

Lower Potsdam Formation (=Ausable Member?)

The Potsdam Formation, in the area of this field trip, includes a basal sequence of arkosic sandstone and conglomerate that reaches a maximum thickness of ~30 meters. The succeeding marine quartz sandstones of the Keeseville Member reach a maximum of ~50 meters. The basal arkosic unit is discontinuous in distribution, with the most extensive and thickest development limited to the area south of Ticonderoga Village along NYS Route 22 (Figure 1). Outside of this area, the Keeseville Member rests directly on Proterozoic basement. The basal arkosic unit is dark green to gray-green or yellowish green in color, massive to thick-bedded, irregularly laminated, cross-laminated fine pebble conglomerate and sandstone. Reverse and normal graded beds 5-20 cm thick are common, and trough cross-beds are present. This unit

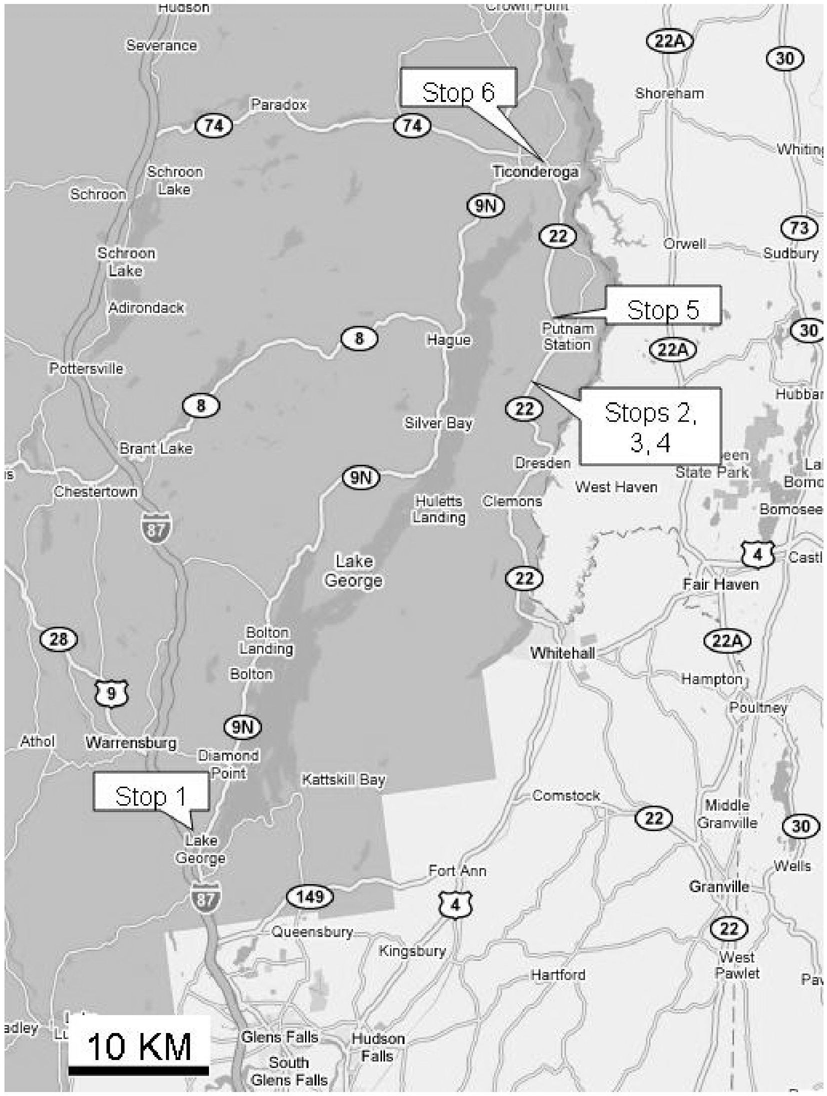

Figure 1 - Location Map
(from Google Maps)

resembles the Ausable Member of the Potsdam Formation in the northern Lake Champlain Valley. The depositional environments of the basal arkosic unit have been interpreted as alluvial fan and braided stream, based upon sedimentary textures, bedded thickness and primary structures (McCrae, et al, 1986). The source area of the sediment was local, since clasts of granitic and calc-silicate gneiss are common in the conglomerates of the basal unit.

The age of the basal arkosic unit in the southern Lake Champlain Valley is not well-constrained. Fisher (1977) proposed that the Ausable Member and related basal arkosic faciesof the Potsdam Formation might be late Proterozoic (Hadrynian) in age, based on the assumption that these facies accumulated in rift basins developed on the margins of the opening Iapetus Ocean. McRae, et al (1986) used paleomagnetic techniques to determine a poorly-cosntrained early Paleozoic depositional age for the Ausable member and other basal Potsdam Sandstone units in the northern New York State outcrop belt. However, the intense post-depositional alteration of the Potsdam Sandstone suggests that the primary depositional paleomagnetic signal was not preserved, and that the remanence measured is likely a diagenetic artifact. The recent description of a trilobite-bearing unit, the early-middle Middle Cambrian “Altona Formation”, beneath the Ausable Member in the northern Lake Champlain Valley (Landing, 2007), requires a Middle Cambrian age for type Ausable Member. In the southern Lake Champlain Valley, quartz sandstones and carbonates of the marine Keeseville Member of the Potsdam contain a uppermost Middle Cambrian trilobite fauna (Landing, 2007). The marine facies of the Potsdam in this area contain local beds of coarse, locally derived clastics, and the contact between the basal arkosic facies and overlying Keeseville is apparently conformable, and represents a marine transgressive surface. These factors suggest relatively continuous deposition during the time interval represented by the basal arkosic unit and overlying marine Keeseville Member, and thus a middle-late Middle Cambrian time of deposition for the basal unit is suggested (Figure 2).

The green basal Potsdam facies contains abundant iron-rich chlorite (Selleck, 1997) that is consistent with diagenetic temperatures in excess of 200°C. The muddy matrix of the sandstones also contains illite and minor kaolinite. Quartz cement and overgrowths of authigenic feldspar on detrital grains are common. Titanium oxide (anatase) cements are present. Associated authigenic REE minerals (monazite, xenotime, allanite), sulfides (pyrite, galena, sphalerite), fluorite and barite suggest that hydrothermal fluids were transmitted through permeable basal sands, causing extensive alteration. Primary detrital minerals such as hornblende, bitotite, plagioclase, garnet and ilmenite are commonly altered to mixtures of chlorite, illite, anatase, quartz, K-feldspar and pyrite. Fluid inclusions in quartz veins which cross-cut the basal Potsdam in the study area have homogenization temperatures near 250 °C and salinities at or near halite saturation (Collins-Waite, 1991). Whitney and Davin (1987) suggested that hydrothermal alteration of Proterozoic basement gneiss in the Fort Ann, NY region was the result of explusion of connate brine from the overlying Paleozoic sediments during the Late Ordovician Taconic Orogeny. This proposition is supported by recent U-Th-Pb chemical age dating of monazite overgrowths in the basal Potsdam, which contain Late Ordovician (ca. 450 Ma) growth zones. Hydrothermal alteration of basement rocks in the area is also manifested by dolomitization of Proterozoic marble (Selleck, 1997). The dolomitization was driven by fault-related fluid flow and was likely contemporaneous with dolomitization of the overlying carbonate rocks in the Potsdam Sandstone and younger Beekmantown Group strata.

Upper Potsdam Formation (=Keeseville Member)

The quartz-rich sandstones of the upper Potsdam Formation are divisible into four lithologic packages which can be correlated over the southern Lake Champlain Valley region (Figure 3).

1. Lower stratified unit: Medium to fine-grained, parallel laminated and cross laminated subarkosic arenite. This unit has a sharp contact but conformable contact with arkosic facies below, often with a conglomeratic ravinement bed at the contact. Where the basal arkosic unit is absent, the lower stratified unit lies nonconformably on Proterozoic basement. Mudcracks and small, irregular burrows are present in silty carbonate-cemented sandstones near the base of the unit. Wave-ripple surfaces are common. Some beds are cemented by pyrite.

2. Lower cyclic unit: Medium to coarse sandstone and fine pebble conglomerate with decimeter-scale dolomite and dolomitic sandstone beds. Dolomitic beds may contain stromatolites, mudcracks and intraclast breccia. Bi-directional cross-stratification is prominent, forming trough cross-sets. Pebbles of locally-derived pegmatitic quarz and feldspar are common. Contact with the underlying lower stratified unit is sharp and marked by abrupt appearance of coarse, pebbly sandstone. Lower cyclic unit unconformably overlies Proterozoic basement in outcrops north of Fort Ann, New York.

3. Upper stratified unit: Medium bedded, coarse to medium-grained quartz sandstone with thin beds of dolomitic silty shale. Horizontal burrows (Rusophycos, Teichichnus) and vertical burrows (Diplocraterion, Skolithos) are present. Most beds are horizontally laminated with beds having overall lenticular form. Wave ripple lamination and wave rippled surfaces common. Contact with underlying lower cyclic unit is sharp, with uppermost beds of the underlying unit consisting of phosphatized, burrowed hardground. Bedsimmediately above the contact are dolomitic and contain abundant lingulid brachiopods and dolomitized shell debris.

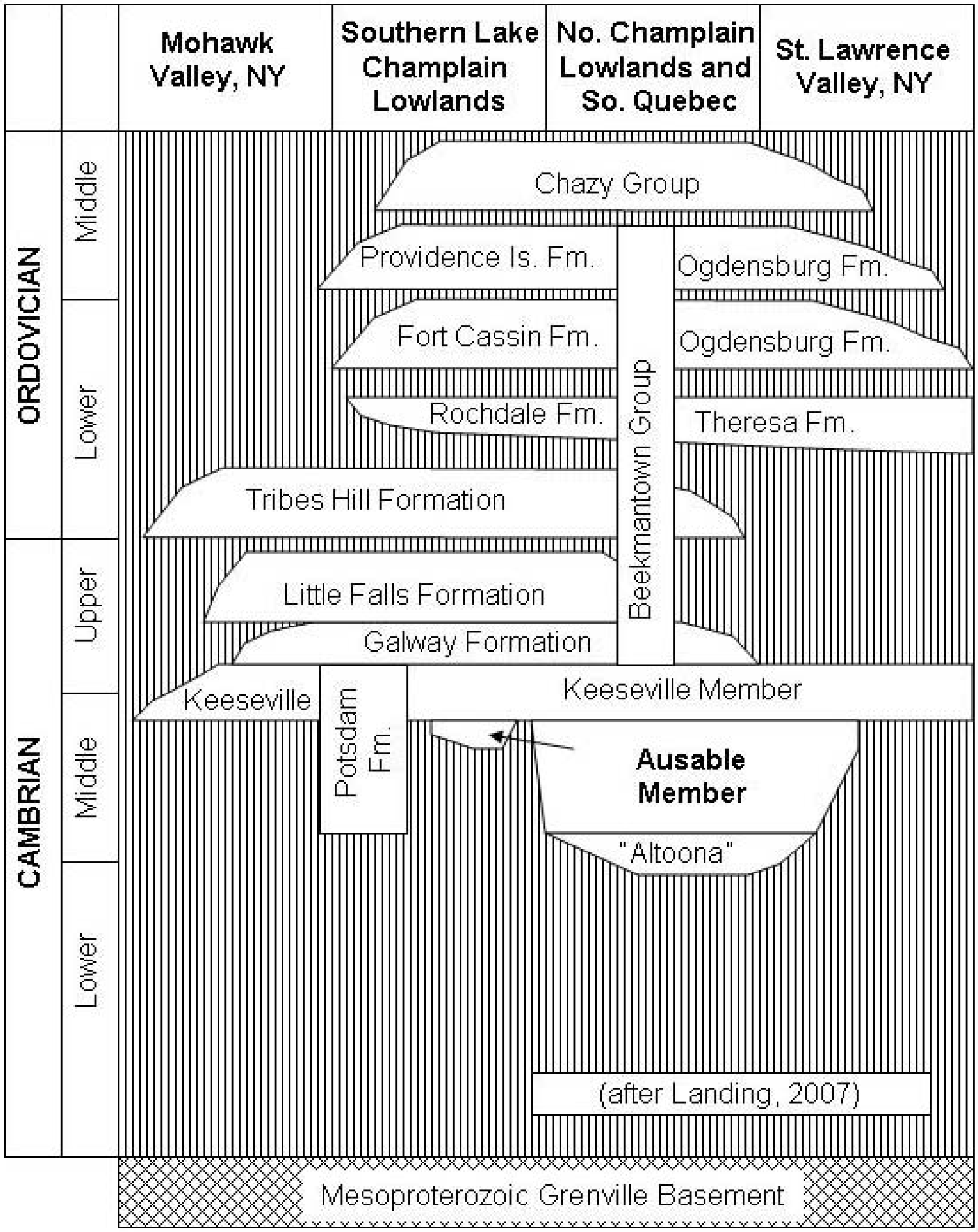

Figure 2 – Regional Stratigraphic Relationships. After Landing, 2007

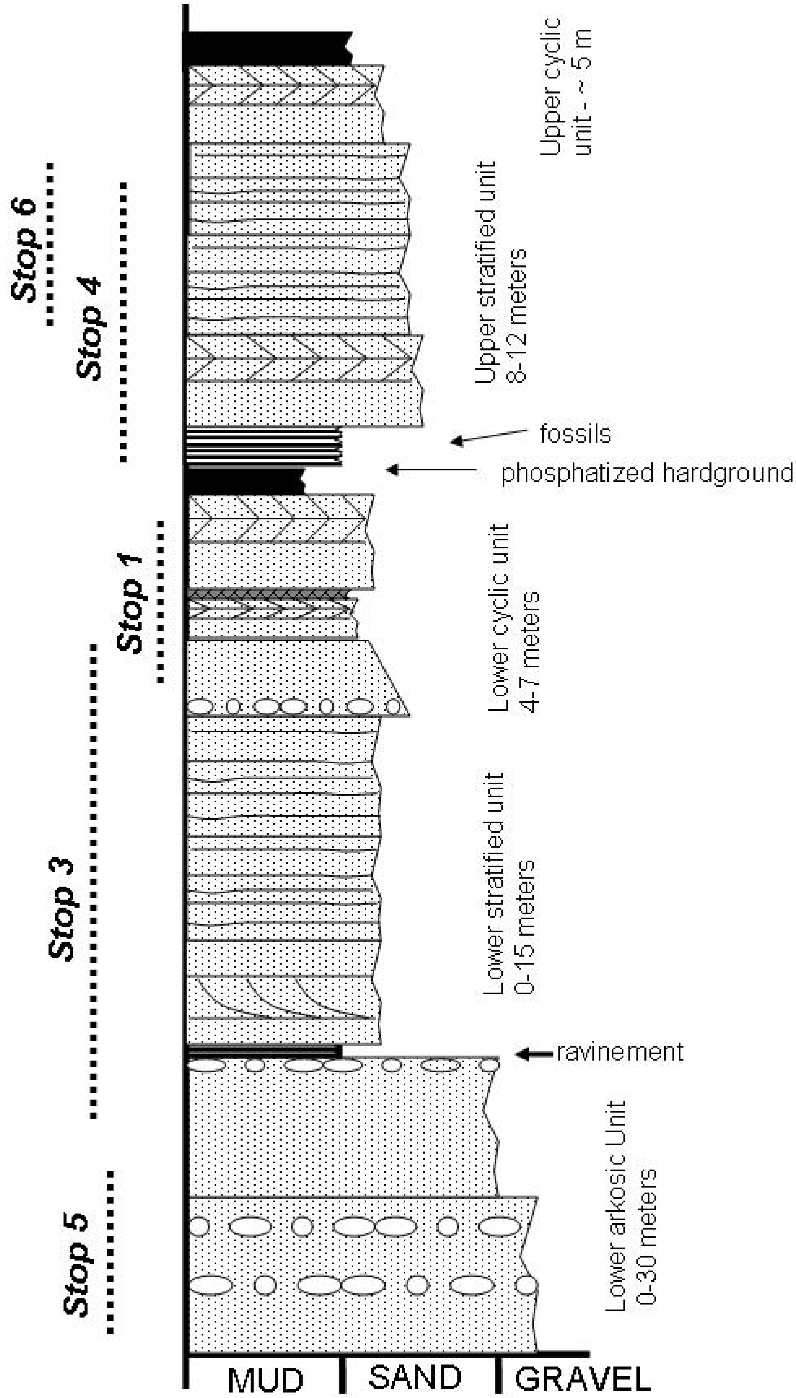

Figure 3 – Schematic composite columnar section for Potsdam Formation in Southern Lake Champlain Valley and Lake George Region

Dolomitic sandstone and calcareous siltstone forming the lowest portion of upper stratified unit exposures near Fort Ann, New York contain an uppermost Middle Cambrian fauna (Landing, 2007). The large trace fossil Climactichnites has been described from quarried slabs of the Potsdam Formation from Port Henry, New York (Yochelson and Fedonkin (1993). Although no specimens have been observed in place, older quarries in the Port Henry area are within the upper stratified unit of the Potsdam, and the slabs bearing Climactichnites at Port Henry most closely resemble the upper stratified unit. Yochelson and Fedonkin (1993) concluded that Climactichnites is restricted to upper Middle and Late Cambrian strata, consistent with the occurrence of uppermost Middle Cambrian trilobites in the upper stratified unit.

4. Upper cyclic unit: Thick to massive bedded, medium to fine quartz sandtone with decimenter-scale beds of burrowed, carbonate cemented fine sandstone. The burrowed units recur at 1-2 meter intervals. Vertical burrows are common, and mudcracks are present in carbonate-rich intervals. Contact with the underlying upper stratified unit is gradational and marked by appearance of burrowed, carbonate-cemented beds.

The uppermost beds of the upper cyclic unit of the Potsdam Formation contain progressively more carbonate up-section, and grade into the basal Galway Formation, which consists of dolomitic sandstone and dolomite. This contact can be observed in the exposures east of the Champlain Canal in the village of Whitehall, New York, where the uppermost Potsdam is succeeded by brown-weathering dolomite and dolomitic sandstone of the Galway Formation in the ledges immediately east of Skene Manor. In the village of Ticonderoga, basal beds of the Galway Formation consist of cherty dolomite with calcite-filled vugs and irregularly weathered brown dolomitic sandstone. These beds are exposed on the northwest side of the village near Mt. Hope Cementary, with white-yellow weathering ledges of upper Potsdam Sandstone found in backyards and scattered field exposures down slope and south of the cemetery.

Sedimentary Environments

The upper Potsdam Formation (=Keeseville Member) in the study area were deposited in shallow marine shoreface, foreshore, offshore subtidal shelf and tidal flat settings. The lower stratified unit records a regional sea level rise, with the shoreline transgressing over non-marine basal Potsdam, where present, and over Proterozoic basement elsewhere. Shoreline stabilization and renewed input of coarse clastics are recorded in the coarse-grained, rhythmically bedded tidalite facies of the lower cyclic unit. A second pulse of sea level rise is represented by the phosphatized hiatus surface which caps the lower cyclic unit, and is succeeded by offshore subtidal facies of the upper stratified unit. This unit then shallows into the tidal flat facies of the upper cyclic unit.

REFERENCES CITED

Collins-Waite, D., 1991, Diagenesis of the Cambro-Ordovician Beekmantown Group: a petrographic and fluid inclusion study; Unpublished M.S. Thesis, SUNY Binghamton, 126 pp.

Fisher, D. W., 1968, Geology of the Plattsburgh and Rouses Point New York-Vermont Quadrangles; New York State Museum Map and Chart Series #10, 51 pp.

Fisher, D. W., 1977, Correlation of the Hadrynian, Cambrian and Ordovician rocks in New York State; New York State Museum Map and Chart Series #33, 133 pp.

Landing, E., 2007, Ediacaran-Ordovician of east Laurentia – Geologic setting and controls on deposition along the New York Promentory region; in Ediacaran-Ordovicain of East Laurentia-S.W. Ford Memorial Volume, New York State Museum Bulletin 510, E. Landing, Editor, p. 5-24

MacRae, L., Johnson, G., and Johnson, N., 1986, Temporal reevaluation of late Hadrynian non-marine facies in the Adirondack border region, New York State, southeastern Ontario and southwestern Quebec; Abstracts with Programs, Geology Society of America, 18, 1, p. 54

Selleck, B., 1997, Fluid-basement interaction at the Proterozoic-Paleozoic unconformity, Adirondack periphery, New York State; Abstracts with Programs, Geological Society of America, 29, 1, p. 48

Whitney, P. and Davin, M., 1987, Taconic deformation and metasomatism in Proterozoic rocks of the easternmost Adirondacks; Geology, 15, pp. 500-503

Yochelson, E. and Fedonkin, M., 1993, Paleobiology of Climactichnites, an enigmatic Late Cambrian fossil; Smithsonian Contributions to Paleobiology, #74, 74 pp.

ROAD LOG

Cum. Miles	Miles from Last Stop	(this road log begins at the exit from the parking lot of the Fort William Henry Hotel in Lake George Village)
0.0	0.0	Exit parking lot and turn right (north) on NYS Route 9N
0.8	0.8	Bear to right at light; continue on NYS Route 9N
1.2	1.2	Turn left at light on I87 access road.
1.4	1.3	Park on right next to low road cuts. UTM 604427E, 48110007N (UTM is NAD83)

Stop 1 – Lower cyclic unit of Keeseville Member, Potsdam Formation

The low outcrops by the roadside display gray-white quartz arenite of the lower cyclic unit of the Potsdam Formation with interbeds of reddish-brown dolomite and dolomitic sandstone. The quartz sandstone units are cross-laminated and trough cross-sets are present. The uppermost layer in the outcrop is comprised of domal stromatolites – algal accretionary structures – that formed in a shallow, muddy tidal pond. Modern stromatolites having this geometry are developed in coastal saline lagoons such as Lake Clifton in Western Australia. The stromatolitic laminations are very well preserved, and the grainy material between individual heads includes quartz sand and dolomitized bioclastic material. Coarse intraclast breccia is also found between individual heads. Note the coarsely crystalline calcite within the cores of some stromatolites. This may be a replacement of gypsum that grew as an evaporite mineral in the sediment that hosted the stromatolites.

Note the minor faults in the outcrop. Some of the patterns of faulting appear to mimic the major graben structure of Lake George and the boundary between the Adirondacks and Champlain Lowlands.

Cum. miles	Miles from last Stop	
1.3	0.0	Turn around and continue to intersection with Route 9N.
1.4	0.1	Turn right (south) onto NYS Route 9N and continue south through Lake George Village
3.9	2.6	Interstate 87 entrance to right; stay on Route 9N south
6.2	4.9	Interesection with NYS Route 149; turn left (east) onto Rt. 149
10.6	9.3	Intersection with Route 9L; continue east on Rt. 149
17.9	16.6	Intersection with NYS Route 4 in Fort Ann, New York; turn left (north) on

		Rt. 4. Continue north
21.0	20.7	Intersection with NYS Route 22; continue north on Rts. 4+22
27.7	26.4	Intersection of Rt. 4 and Rt. in Whitehall; continue north on Rt. 22. Skene Mountain to east includes exposures of Potsdam Formation and overlying Beekmantown Group carbonates
41.9	40.6	Park on right next to low outcrop of marble. UTM 626390E, 4841026N

Stop 2 – Proterozoic marble with Paleozoic dolomitization features

The roadcut on the east side of Route 22 displays dolomitized Proterozoic basement marble. Note the very coarse crystal size of the unaltered calcite marble and the pseudomorphic dolomite in the dolomitized portions. Graphite with the calcite marble is not altered in the dolomitized marble. The coarse dolomite crystals contain mm-scale voids that are sometimes partially filled with tiny 'saddle' dolomite rhombs, and terminated calcite and quartz crystals, which resemble miniature Herkimer 'diamonds'. Note the vertical fractures in the marble which served as conduits for the dolomitiziting fluid. This is a good exposure to examine the effects of enhanced permeability, produced during the dolomitization process, on the development of a 'dolomitization front'. Alteration of calcsilicate minerals (clinopyroxene, brown phlogopite mica) in the dolomitized marble may have served as a source of magnesium for dolomitization. The relict altered minerals are now represented by chlorite and illite pseudomorphs. Pyritiferous, cherty, chlorite-bearing lithologies on the west side of the highway are also the result of hydrothermal alteration accompanying the dolomitization.

Saddle dolomite crystals within vugs in the dolomitized marble contain aqueous 2-phase fluid inclusions with homogenization temperatures of 160-210°C. Ice melt temperatures of these inclusions indicate salinity near halite saturation; similar high salinity inclusions are also found in sparry dolomite in the overlying Beekmantown Group carbonates (Collins-Waite, 1991). Stable isotopic analysis of the calcite and dolomite suggest interaction of the marble with dolomitizing fluids that were isotopically enriched relative to seawater, and that the fluids were strongly rock-buffered (Selleck, 1997).

The broad valley to the north of this road cut is underlain by Potsdam Formation; Stop 3 is visible approximately 2 km to the north along Route 22. The local geology suggests that the marble exposure here was close to the overlying Potsdam, and thus fluids within the Potsdam were readily available to invade the marble along vertical fractures. Enhancement of permeability within the marble by dolomitization increased the access of fluids to the basement rocks.

Cum. miles	Miles from last Stop	
41.9	0.0	Continue north on NYS Route 22
43.8	2.1	Park on right adjacent to southern end of outcrop. UTM 627686E, 4843461N

Stop 3 – Lower Potsdam Sandstone at Firehouse Road

These road cuts expose the upper part of the basal arkosic unit, the succeeding lower stratified unit and the lower cyclic unit of the Potsdam Sandstone. We will examine the basal arkosic unit in more detail at Stop 5. The contact between the basal arkosic unit and the overlying lower stratified unit is well-displayed on both sides of the road. Note the abundant large clasts at the contact. This layer is interpreted as a lag deposit on a ravinement surface formed by the reworking of previously deposited gravel and sand by the encroaching marine shoreline during sea level rise. The immediately overlying marine sandstone contains rare mudcracks, best seen in the silty layers less than a meter above the contact. Rare vertical burrows are sometimes visible in outcrop, but common in slabbed samples of the sandstone 2-3 meters above the contact. Note the dominantly horizontal stratification and tabular foreset cross-stratification. Trough cross-sets are also present. This facies is interpreted as a shallow subtidal foreshore deposit.

Continuing up-section at this outcrop, the base of the lower cyclic unit is marked by reappearance of coarse pebbly sandstone that documents shallowing to an intertidal depositional setting; availability of local Proterozoic basement source rocks is indicated by pebbles of vein quartz and feldspar. Well-developed bipolar cross lamination is clearly seen on vertical faces. The coarse pebbly sandstone intervals are capped by medium sandstones and carbonate beds at approximately one meter intervals. The carbonate beds consist of ferrroan dolomite with late calcite veinlets and vugs; and are interpreted as accumulations of carbonate mud on shallow upper intertidal flats. In other outcrops of this facies in the area, the carbonate beds contain stromatolites, mudcracks and intraclast breccia. Note the buckling and truncation of some of the carbonate beds. Sulfide mineralization is common in the carbonate, with pyrite, sphalerite and galena present. The dolomitization and sulfide mineralization are assumed to be related to the same hydrothermal event(s) which caused the dolomitization of marble seen at the last stop.

Cum. miles	Miles from last Stop	
43.8	0.0	Continue north on Rt. 22
44.3	0.4	Park on right side of Route 22. UTM 628278E, 4844038N. Be careful crossing the highway!

Stop 4 – Upper Potsdam Sandstone at Firehouse Road

The upper part of the lower cyclic unit and the succeeding upper stratified unit of the Potsdam Sandstone are exposed in the outcrops on the west side of Route 22. Scattered low outcrops to the south allow for a nearly complete section to be constructed in these exposures. The lowest beds on the southern end of the roadcuts are dolomitic sandstones of the lower cyclic unit. A phosphate mineralized hardground with large burrows is developed at the top of these beds. This surface, interpreted as a sediment starvation interval that records the onset of a period of sea level rise, marks the contact between the lower cyclic unit and the upper stratified unit. The succeeding beds of the upper stratified unit consist of sandy dolomite, dolomitic shale and silty sandstone. The dolomite beds contain fragmentary lingulid brachiopods, dolomitized bioclasts, vertical and horizontal traces including Rusophycos and Teichichnus, intraclast breccias and wispy phosphatized surfaces. This interval is apparently correlative to the beds near Fort Ann, New York that have yielded a uppermost Middle Cambrian trilobite fauna. Diligent searching at this outcrop has not recovered identifiable trilobite remains, but it is a likely target for further study.

The upper stratified unit coarsens rapidly above the basal beds with coarse bipolar cross-stratified sands documenting storm or tidal current effects. Medium bedded sandstone with thin silty shale interbeds form the bulk of the exposures. Note the lensoid character of the bedding in the middle and upper portion of the outcrop. The uppermost part of the outcrop is thicker-bedded and slightly coarser sandstone. The upper stratified unit facies is interpreted as a lower shoreface and foreshore subtidal deposit, documenting a deepening event followed by shallowing. Exposures in the forested area immediately north and west of this outcrop are within the lower portion of the upper cyclic unit, and record further shallowing to tidal flat facies. We will not examine these exposures on this trip. Note the prominent fault-line scarp to the west and north of the highway. We will cross this fault as we proceed north to Stop 5.

Cum. miles	Miles from last Stop	
44.3	0.0	Continue north on Rt. 22

45.8 1.5 Park on right side of Route 22. Be careful crossing the highway!

Stop 5 - Basal arkosic unit of the Potsdam Formation

The angular non-conformity separating banded Proterozoic calcsilicate gneiss and the basal arkosic unit of the Potsdam Formation is very well-displayed in road cuts on both sides of Route 22. The gneiss below was deformed in the Ottawan Orogeny, ca. 1050 Ma. The Potsdam here is ca. 520 Ma.

Medium to thick-bedded arkosic wacke, and arkosic arenite with abundant quartz and feldspar pebbles form the basal arkosic unit at this stop. Coarser lenses of pebble conglomerate occur discontinuously above the basal contact, and are sharply overlain by sandstone. These lenses represent an earlier phase of gravel deposition. The main body of sandstone contains normal and reverse graded beds. This facies was deposited by mass flow and sheet flood processes in a high-gradient fluvial system.

The gray-green color of the sandstone is due to iron-rich chlorite (25-29 wt. % total FeO). The chlorite formed as a diagenetic replacement of hornblende, garnet, biotite and plagioclase. Chlorite also occurs as an integranular cement with quartz, K-feldspar and anatase. Chlorite occurs as tabular crystals within fluid inclusions in vein quartz at this outcrop, suggesting that the vein-mineralizing fluids were similar to those causing the general diagenetic alteration. Chemical data indicate that the diagenesis of the basal arkosic facies involved exportation of sodium, magnesium and calcium from the original sediment. This is consistent with petrographic observations, notably conversion of plagioclase, hornblende, biotite and garnet to Fe-chlorite. Chemical data also require importation of potassium and iron by diagenetic fluids.

The magnesium lost for the primary detrital minerals during burial diagenetic alteration may have served as a source of magnesium for dolomitization of underlying marble (Stop 2) and overlying marine carbonates (Stop 3). Similar Fe-chlorite alteration occurs in Proterozoic basement rocks and these could also have served as a source of magnesium for dolomitization. The widespread occurrence of these features in the vicinity of faults in this region suggest that seismic pumping of diagenetic/hydrothermal fluids was an important process during fluid alteration of the basement and overlying sedimentary strata. Other metals (Cu, Pb, Zn) in the original depositional minerals were also mobilized and exported via hydrothermal fluids, documented by scattered, non-economic occurrences of galena, sphalerite and chalcopyrite in the Potsdam Formation sandstones and in carbonates of the Beekmantown Group.

The diagenesis of the basal arkosic unit also resulted in precipitation of REE-bearing minerals. The yttrium phosphate mineral xenotime is found as scattered grains within authigenic chlorite and as authigenic overgrowths on detrital zircon grains. Monazite occurs as ‘meshwork’ replacement of detrital allanite and as overgrowths on detrital monazite grains. Thorite is present as detrital grains and micron-scale crystals within authigenic quartz. The source of the REE was the original sediment, which contained detrital grains of allanite, which is rather common in the adjacent Proterozoic granites and REE from breakdown of minerals such as garnet, ilmenite and magnetite. Detrital grains of ilmenite and magnetite in the basal arkosic unit are often altered to intergrowths of chlorite and anatase. Authigenic pyrite, sphalerite, galena and chalcopyrite are common in the green sandstones at this locality.

Collins-Waite (1991) reported fluid inclusions with 200-300° homogenization temperatures in vein quartz hosted by the sandstone at this locality. Fluids in the inclusions are halite-saturated. The quartz crystals hosting the inclusions show strong inclusion zoning patterns, suggesting a series of pulses of fluid flow and quartz crystal growth.

Cum. miles	Miles from last Stop	
45.8	0.0	Continue north on Route 22
49.7	3.9	Intersection with Route 74 and Montcalm Street; turn left (west) onto Montcalm Street
50.1	4.3	Park near picnic area on right. UTM 627148E, 4856272N

Stop 6 – Potsdam Sandstone in Ticonderoga Village at LaChute River Falls

The upper stratified unit of the Potsdam Formation forms the water fall on the LaChute River in Ticonderoga Village. The hydroelectric plant excavations in the mid-1990's provided an opportunity to inspect the underlying carbonate-bearing lower cyclic unit. The overlying upper cyclic unit can be observed in scattered outcrops up slope to the north of the river exposures. Basal beds of the Galway Formation are present further up slope, near the road adjacent to Mt. Hope Cemetery. The sandstone slabs used in construction of the building at the hydroelectric site are from the upper stratified unit of the Potsdam. Note that some of these bear the trace fossil Protichnites.

End of trip – to return to Interstate 87, follow Rts. 22 and 74 north from last intersection; continue west on Route 74 to I87; to return to Lake George Village, continue on Montcalm Street though Ticonderoga Village; take Rt. 9N south to Lake George.