TRIP B3

SEDIMENTOLOGY AND DIAGENESIS OF THE POTSDAM SANDSTONE AND THERESA FORMATION, SOUTHWESTERN ST. LAWRENCE VALLEY

BRUCE W. SELLECK
Department of Geology
Colgate University
Hamilton, NY 13346

INTRODUCTION

The lower Paleozoic strata in the southwestern St. Lawrence Valley consist of the Late Cambrian-Early Ordovician Potsdam Sandstone, Theresa Formation and Odgensburg Dolostone. This sequence totals approximately 120 meters in thickness, and is the age equivalent of the considerably thicker passive margin carbonate sequence of eastern New York and Western Vermont. In the area of this field trip, the lower Paleozoic sequence is well-exposed along the St. Lawrence River from the vicinity of Ogdensburg to Alexandria Bay, New York. In this area glacial sedimentary cover is thin or absent, and outcrop exposures are common in streams tributary to the St. Lawrence, and as roadcuts. The contact between the basal Potsdam Sandstone and the Late Proterozoic metamorphic and igneous rocks of the Grenville province is well-exposed in the area. The so-called Frontenac Axis is a topographic high in the Grenville rocks, and trends NNW-SSE. Regionally, Paleozoic strata dip gently to the ENE to the east of the Frontenac Axis and to the WSW to the west. The Medial Ordovician Black River Group overlies the Theresa Formation to the southwest of the area of this field trip. To the north and east Early Medial Ordovician Chazy Group strata overlie the Ogdensburg Dolostone and its equivalents.

The Potsdam Sandstone

The Potsdam Sandstone is one of the most widely-exposed units in the circum-Adirondack region of New York State, and is well-known as a building stone, particularly in the area of the type section near Potsdam, New York. In the St. Lawrence Valley, the Potsdam rests unconformably upon Late Proterozoic gneisses, granites, quartzites and other metasedimentary rocks. The Proterozoic rock beneath the unconformity is often rather altered, and in areas where the Proterozoic rock is marble, there are often very complicated relationships between the basement marble and sandstone. These altered zones and complex basement-cover contacts have been interpreted as soil horizons, and pre-Potsdam karst zones. Some workers have proposed that the sandstones in marble terrains may represent infolded Proterozoic sandstones that were not metamorphosed. The best explanation for the alteration of sub-Potsdam basement and the complex sandstone-marble relationships is that the basement rock was extensively altered chemically and mineralogically by hot sedimentary brines that circulated through the porous Potsdam and "attacked" the basement rock. Lateral and vertical transport of sand during brine flow into encavernated marble accounts for the complex features observed. High fluid pressures, perhaps driven by hydrocarbon cracking and methane production, likely characterized this period of brine flow. The production of organic acids during hydrocarbon maturation may have provided a source of aggressive reactants which facilitated dissolution of marble and alteration of silicate minerals in other basement rocks. K-Ar dates on illite associated with hydrothermal minerals in the basal Potsdam suggest that significant activity occurred in Late Devonian-Early Carboniferous time, perhaps when the region was buried deeply, and tectonic disturbance to the east and southeast triggered cratonward flow of fluids.

In the area of this field trip, the Potsdam is divided into a lower portion consisting of medium-coarse quartz arenites that exhibit types of cross-stratification and other primary structures suggesting shallow marine shoreface and subtidal tide-dominated depositional conditions. Non-marine aeolian facies, and braided stream facies are present in the lower Potsdam, but will not be seen on this trip. Conglomeratic facies are common in the Potsdam, but are particularly abundant in the basal portion in the vicinity of quartzite basement exposures. The lower Potsdam is virtually unfossiliferous in this area. Simple vertical living burrows and rare surface crawling traces are present in some of the thin-bedded sandstones. The enigmatic crawling trace *Climachtichnites* is present in slabs used for construction of a wall at the visitor's center of Wellsley Island State Park, near our last stop on the trip. The recent work of Yochelson and Fedonkin suggest that *Climachtichnites* may be limited to the Late Cambrian (Yochelson, personal communication 1990). Other fossils have not been found, and thus the age assignment of the lower Potsdam remains a question.

The lower Potsdam consists almost entirely of well-rounded detrital quartz grains cemented by secondary quartz, illite and rare kaolinite. The coloration of the basal Potsdam is due to finely disseminated iron and titanium oxides, which were formed during diagenetic breakdown of detrital ilmenite and magnetite. Detrital feldspars in the lower Potsdam are generally highly altered to masses of illite and/or kaolinite. The percentage of kaolinite increases abruptly near the contact with the upper unit of the Potsdam, and SEM study indicates that this kaolinite predates secondary quartz cements and illite. Such kaolinite may have formed during weathering and subaerial exposure that accumpanied the depositional hiatus between the lower and upper Potsdam.

Upper Potsdam Sandstone

The upper portion of the Potsdam Sandstone consists of medium-fine quartz sandstones with 3-6% detrital feldspar. Carbonate cements and recrystallized carbonate mud are present, often outlining burrows. The phosphatic inarticulate brachiopod *Lingulepis* is present, but other body fossils have not been found in the area of this study. The upper Potsdam commonly exhibits alteration of meter-scale burrowed and unburrowed facies. The burrowed sections display good examples of the u-shaped burrow *Diplocraterion;* the unburrowed sections expose ripple marks, mudcracks and small-scale bipolar cross-strata with reactivation surfaces. These facies are interpreted as sandy tidal flat environments, with the burrowed sections representing slightly more emergent or well-protected environments, and the cross-bedded and laminated sands slightly more active environments lower on the tidal flat system. The rhythmic repetition of burrowed and unburrowed meter scale units may record high-order sea-level changes. Similar patterns are seen in the middle portion of the Theresa Formation.

The age of the upper portion of the Potsdam has been assigned to the early Ordovician on the basis of a Tremodocian conodont fauna (Greggs and Bond, 1971). As noted above, the contact between the lower and upper units of the Potsdam Sandstone represents a hiatus in deposition of unknown duration. The hiatus is characterized by the development of intraformational sandstone breccias, kaolinite-silica cemented sandstone concretions, and abundant early kaolinite cement. This surface may represent a significant period of terrestrial weathering.

Theresa Formation

The transition from the uppermost Potsdam Sandstone to the lower Theresa Formation is rather abrupt, and at least in some sections marks a deepening from tidal flat facies to near wave-base offshore facies. The basal 5-8 meters of the Theresa Formation consists of thin to medium bedded calcareous and dolomitic siltstones and fine sandstones. Typical beds are 2-10 cm. in thickness, and contain a basal portion that is plane-laminated or ripple cross-laminated, and an upper portion that is bioturbated. These couplets are interpreted as tempestites - storm deposits - with the upper, bioturbated portion representing the recolonization of the substrate following a depositional event. A variety of horizontal grazing trails are present, as well as vertical escape burrows in the laminated basal portion of many beds.

Lingulepis debris is common in the lower portion of the Theresa Formation, and rare discoidal gastropods are found. Conodonts are abundant in some beds. Detrital feldspar may form up to 25% of the siliciclastic material in the lower Theresa. The original sediment is inferred to have been a mixture of siliciclastic silt and sand, with significant amounts of lime mud and other carbonate material. Most carbonate is now in the form of secondary dolomite and coarsely crystalline (neomorphic?) calcite.

The transition from the thin-bedded lower Theresa to the middle Theresa Formation involves overall increase in grain size, and increase in bedding thickness. The middle Theresa is packaged into alternating burrowed and unburrowed units that are grossly similar to the upper portion of the Potsdam Sandstone. The unburrowed units consist of trough and planar-tabular cross-stratified medium sandstones with common bipolar crossbed sets. The burrowed units are slightly finer grained, bioturbated sands with abundant dolomite and calcite. Carbonate may comprise up to 40% of the rock, with dolomite apparently replacing earlier lime mud and carbonate grains, and calcite present as neomorphic spar and late cement. The uppermost portion of the burrowed units is often capped by thin-laminated dolostone with calcite spar-filled voids. These sequences are interpreted as originating from the progradation of tidal flats, with the unburrowed portions representing the more wave and current reworked low tidal flat, and the burrowed, carbonate-rich facies the upper tidal flat, capped by algally-laminated muds. Spar-filled voids in the finer-grained facies may represent early voids formed by shrinkage or dissolution of sediments, or voids formed by later dissolution of evaporites. Significant later diagenetic alteration is indicated by pervasive dolomitization and calcite recrystallization. Pyrite is a common authigenic mineral, and commonly is confined to the darker, carbonate-rich facies. The pyrite may be an early authigenic phase formed during sulfate reduction resulting from shallow burial. Alternatively, the pyrite may have been introduced during later diagenesis that accompanied the movement of regional brines, and thus represents hydrothermal mineralization. The occurrence of galena, chalcopyrite and sphalerite in the upper Theresa and Odgensburg Dolostone suggests that Mississippi Valley Type mineralization occurred on a small scale in the region.

Upper Theresa Formation

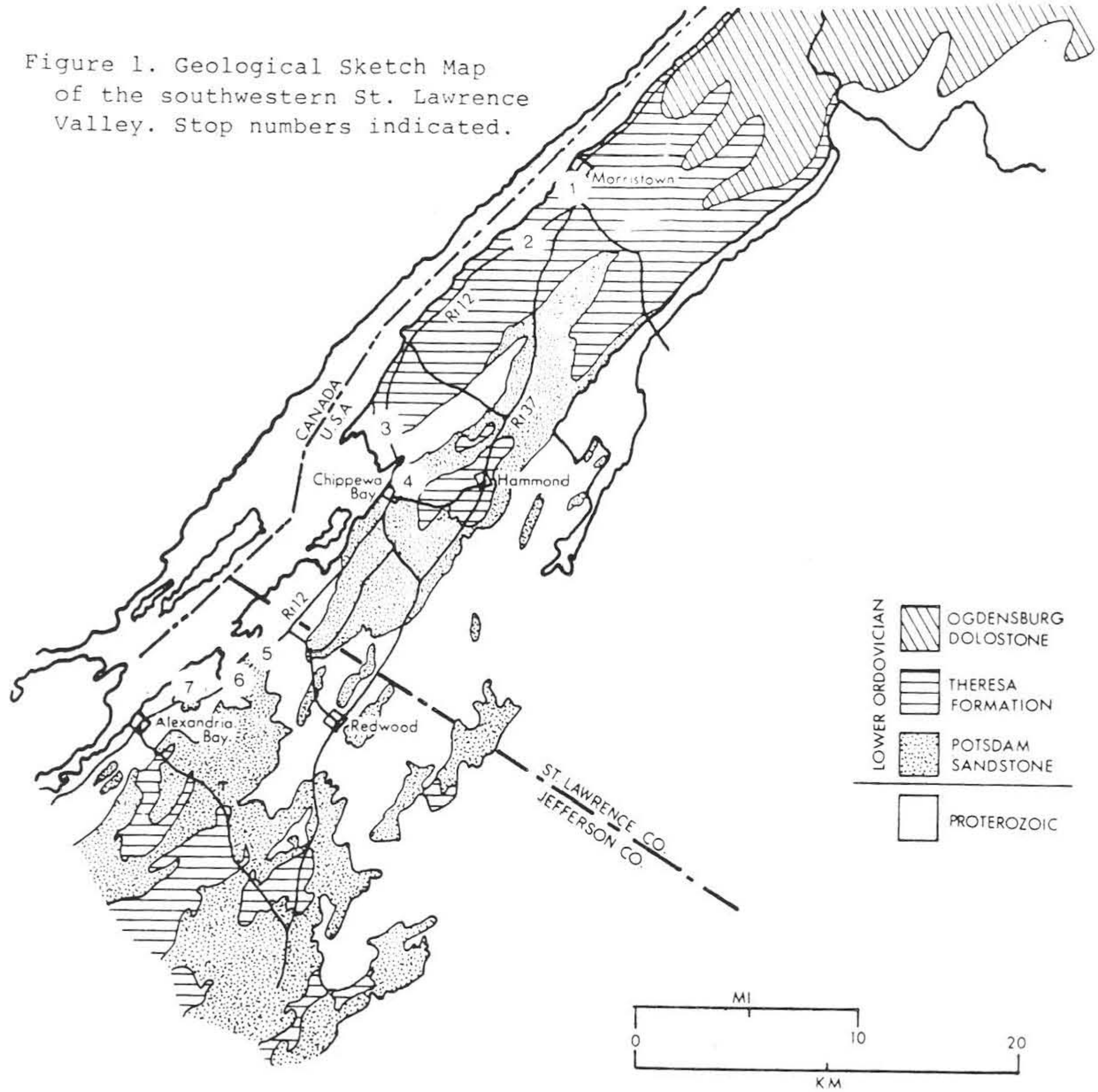
The upper portion of the Theresa Formation differs from the middle portion in the presence of more carbonate-rich beds (sandy dolostones with up to 80% carbonate) and more evidence of subaerial exposure (mudcracks, intraclast breccias). The overall meter-scale pattern of burrowed and unburrowed facies is less regular in the upper Theresa, but evidence of tide-dominated deposition, in the form of bipolar sets of cross-strata, is abundant.

Carbonate-rich beds in the upper Theresa commonly contain abundant voids partially filled by "saddle" dolomite, calcite, quartz, barite, fluorite, pyrite and chalcopyrite. This mineralization is likely related to the regionally pervasive MVT-like hydrothermal mineralization widely observed in the St. Lawrence Lowlands. The timing of this mineralization is likely synchronous with the illite cements present in the lower Potsdam, because illite has been observed intergrown with barite and pyrite in the lower Potsdam. If this is so, then the mineralization occurred in late Devonian-early Carboniferous (355-360 mya), perhaps when regional brines were being transmitted through the sequence. Fluid inclusion studies of quartz crystals from nearby localities in the Ogdensburg Dolostone indicate minimum temperatures in excess of 180 degrees C. and salinities in excess of 25% NaCl equivalent.

REFERENCE

Greggs, R.G. and Bond, I.S. (1971) Conodonts from the March and Oxford formation in the Brockville Area, Ontario; Canadian Journal of Earth Sciences, vol. 8. #11; p. 1455-1471

Figure 1. Geological Sketch Map of the southwestern St. Lawrence Valley. Stop numbers indicated.



ROAD LOG

This field trip will take us through the Theresa Formation and Potsdam Sandstone, and in general we will travel down section, with the first stop in the upper Theresa Formation, and the last stops in the basal Potsdam Sandstone. This route, although not the most desirable (it usually is easiest on the brain to move forward through time, rather than backwards) allows us to end the trip with easy access to Interstate Route 81, at the Thousand Islands International Bridge.

The road log begins at the intersection of Park Street and Route 11 in the Village of Canton, New York.

The road log begins at the intersection of Park Street and Route 11 in the Village of Canton, New York.

Cumulative mileage	Miles from last point	Route description
Start		Junction of Main Street (Route 11) and Park Street in the center of Canton. Follow Route 11 signs out of Canton towards Ogdensburg.
0.3	0.3	Proceed west (straight) onto Route 68
16.9	16.6	Proceed west (left) on Route 37
23.6	6.7	St. Lawrence State Park
28.1	4.5	Stop 1

STOP 1:

Roadcuts on both sides of Route 37 expose tidal flat facies of the upper portion of the Theresa Formation. The basal beds here consist of sandy dolostone with irregular voids containing authigenic dolomite, calcite, quartz, barite and sulfides. Other lithofacies present here include laminated silty dolostones, burrowed dolomitic sandstones and cross-laminated sandstones exhibiting well-developed bipolar cross-sets.

Continue southwest on Route 37.

28.8	0.7	Proceed west (bearing right) onto Route 12
30.6	1.8	Entrance road to Jacques Cartier State Park
31.9	1.3	Stop 2

STOP 2:

The roadcuts at this stop expose the middle portion of the Theresa Formation. The rhythmic interbedding of yellow-white cross-laminated sandstones and darker, burrowed dolomitic sandstones is typical of this portion of the Theresa Formation. The burrowed units are often capped by a few centimeters of laminated dolostone. The cross-laminated sandstones are interpreted as low tidal flat deposits, the burrowed dolomitic sandstones as upper intertidal, capped by algal-stromatolitic carbonate mud. These sequences are tidal flat cycles, and their origin may reflect both high-order sealevel change and tidal flat progradation that produced slight but sudden deepening followed by shallowing due to progradation.

Note the apparent soft-sediment deformation represented by the intraformational folds near the northeast end of the outcrops. Note also the more general low-amplitude folding and the high-angle faults.

Continue southwest on Route 12

35.5 3.6 Stop 3

STOP 3:

The contact between the uppermost Potsdam Sandstone and basal Theresa Formation is exposed on the south side of Route 12 near the southwest end of the outcrop. The contact is marked by the change in color (Potsdam = white-grey-yellow; Theresa = grey-brown), the abrupt increase in carbonate content in the basal Theresa Formation, and the change in bedding thickness from the thick to massive beds of the Potsdam to the thin beds of the basal Theresa. The lower Theresa in this area consist of 2-10 cm. beds of plane-laminated or ripple cross-laminated fine sandstones/siltstones that are capped by calcareous and dolomitic fine sandstones/siltstones. Escape burrows that traverse the laminated beds record attempts of organisms to return to the sediment surface following a sudden influx of sediment. The environment of the lower Theresa is interpreted as a subtidal, near wave base shelf lagoon setting characterized by sporadic sediment influx and physical disturbance of the bottom (storms). These events produced laminated and cross-laminated sheets of sand and silt, the tops of which were subsequently colonized by organisms, producing the bioturbated tops on each bed.

The upper Potsdam Sandstone at this stop consists of burrowed calcareous sandstones and laminated and cross-laminated sandstones that generally resemble the middle portion of the Theresa Formation seen at the last stop. The trace fossil *Diplocraterion* is common in the burrowed units, and a alternating low tidal flat - high tidal flat environment is envision for these facies. Fragments of the brachiopod *Lingulepis* are common in the upper Potsdam and lower Theresa at this stop. The lower Theresa here also contains scattered pebbles and cobbles of quartzite that were clearly derived from a Proterozoic basement knob exposed approximately 300 meters south of this outcrop.

Continue southwest on Route 12

38.8 3.3 Stop 3a

STOP 3a:

This stop replicates the sequence observed at our last stop, and we will only stay a short time to examine the features of the upper Potsdam Sandstone, which are somewhat better exposed here. Very well-preserved examples of *Diplocraterion* are present in the upper Potsdam on the southeast side of the outcrop.

Note the outcrop of Proterozoic basement immediately to the southwest along Route 12.

Continue southwest on Route 12.

40.4	1.6	Stop 4

STOP 4:

The contact between the lower and upper portions of the Potsdam Sandstone is exposed in the roadcut on the southwest side of Route 12. The lower section of the outcrop consists of medium-bedded, cross-laminated, medium-grained sandstones typical of the lower Potsdam. The upper, massive calcareous sandstone bed is highly burrowed, and is the base of the upper Potsdam. This facies of the lower Potsdam is interpreted as a shallow, wave and tidal current dominated shelf.

The contact between the lower and upper Potsdam represents a depositional hiatus of some duration. Networks of vertically-oriented cracks, brecciated sandstone and kaolinite-cemented concretions are common along this horizon, which is widely traceable throughout the St. Lawrence Lowlands, and clearly represents a sealevel lowstand. As noted in the text, the lower Potsdam may be Dresbachian, based upon the occurrence of *Climactichnites*, whereas the upper Potsdam is Tremadocian, suggesting that a portion of the upper Cambrian is absent due to non-deposition, or erosion, prior to deposition of the upper Potsdam.

Continue southwest on Route 12.

47.6	7.2	Stop 5

STOP 5:

The unconformity between the basal Potsdam Sandstone and underlying Proterozoic gneisses is exposed in the roadcut on the southeast side of Route 12. The time interval represented by this contact is some 600 million years. The basal sandstones here exhibit large-scale low-angle planar-tabular cross-bedding, and are devoid of fossils. The depositional setting for this facies is problematic, although shallow marine tidal inlet, shoreface, and perhaps even aeolian dune environments are possible facies models.

Considerable variation in color pattern is evident in the lower Potsdam here, with the basal meter or so consisting of white to light grey sandstone, and the remainder of the outcrop showing pink, red, orange and salmon colors often seen in the Potsdam used as building stone.

The colors here are due to finely crystalline hematite, goethite and anatase (=leucoxene) which form pigments around the detrital grains and within secondary quartz and illite cements. The iron and titanium for these pigments were derived from the breakdown of detrital magnetite and ilmenite grains in the original sediment. Paleomagnetic studies at this outcrop suggest that the iron-bearing minerals were precipitated in late Paleozoic time. The white sandstones at the base of the Potsdam contain no hematite or anatase, although limonite-goethite halos of relatively recent origin are developed around some magnetite grains.

Note the alteration of the underlying gneisses immediately beneath the Potsdam. The alteration assemblage here consists of illite, Fe-chlorite (or berthierine), siderite and quartz.

Continue southwest on Route 12.

48.8 1.2 Stop 6

STOP 6:

The roadcut on the southeast side of Route 12 exposes typical lower Potsdam Sandstone. Plane-bedded medium- and fine-grained sandstones underlie and overlie a one meter thick bed of cross-bedded medium sandstone. The dominant cross-bed dip direction is SSW. Above the thick cross-bedded unit small-scale cross-strata dip to NNE. As with many exposures of the lower Potsdam, the environment of deposition is difficult to assign. Although the flat-bedded sandstones lack trace or body fossils, a shallow marine environment is suggested by the continuity of individual beds, the lack of upward fining or coarsening trends, and the lack of channel form geometry. However, definitive primary structures are absent. The thick cross-bedded unit was produced by a bedform of perhaps two or three meters in amplitude. Stoss-side erosion beveled the upper portion of the structure as it migrated, leaving behind a scoured lag deposit of granules at the updip termination of the cross-strata. A structure of this size and geometry could be produced by tidal currents or by wind during a period of emergence.

Continue southwest on Route 12.

50.2 1.4 Stop 7

STOP 7:

The unconformity between the basal Potsdam Sandstone and Proterozoic gneisses is again exposed in these large roadcuts on both sides of Route 12. The dominant facies here is typical of the lower portion of the Potsdam. Flat-stratified medium- and fine-grained sandstones are interrupted by 0.2 to 1.0 meter thick sets of cross-strata. The lack of trace and body fossils again makes assignment of a depositional environment somewhat difficult.

Note the altered gneiss immediately beneath the contact. Illite, Fe-chlorite, and siderite form the alteration assemblage. The sandstones immediately above the contact contain abundant authigenic illite, which has been K-Ar dated at 355-360 million years.

Continue southwest on Route 12

56.0	5.8	Proceed north on Interstate Route 81
64.3	8.3	Optional Stop 8

STOP 8 (optional stop, time permitting):

These long roadcuts on Interstate Route 81 expose a sequence of conglomerates and pebble-cobble sandstones in the Potsdam Sandstone. The quartzite cobbles in these exposures were derived from a basement quartzite ridge immediately to the south. At least some of the conglomerate beds here were emplaced by mass flow mechanisms, perhaps as sandy debris flows. Wave reworking of the tops of mass flow beds indicates that the sands and gravel were deposited in a marine setting. Near the top of the exposure the contact between the lower and upper Potsdam is present, and burrowed calcareous sandstones succeed the conglomeratic facies.

END OF TRIP.

(To return to Interstate Route 81 South, exit at the DeWolf Point exit approximately three miles north of the last stop. Turn left off the exit ramp to head south on I81)