1-1-1980

Structure and Sedimentology of Siluro- Devonian Between Edmunston and Grand Falls, New Brunswick

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Trip C-7

STRUCTURE AND SEDIMENTOLOGY OF SILURO-DEVONIAN BETWEEN EDMUNDSTON AND GRAND FALLS, NEW BRUNSWICK

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Introduction

The Ordovician, Silurian and Lower Devonian sediments of the Edmundston - Grand Falls area in northwestern New Brunswick are exposed in Acadian (Devonian) anticlinoria and synclinoria (Fig. 1) within which subsidiary major and mesoscopic folds are present (Hamilton-Smith, 1970; St. Peter, 1977). The anticlinorium near Grand Falls (Fig. 1) is part of the Aroostook-Matapedia anticlinorium which extends from Maine across New Brunswick to the eastern end of the Gaspé peninsula in Quebec (Rodgers, 1970; Williams, 1978). The lithologies of the folded formations and their stratigraphic correlation within the area are indicated in Table 1. The sediments are predominantly fine-grained greywackes and constitute the Aroostook-Matapedia belt.

Tight upright folds and an associated steep to vertical cleavage are characteristic structural features of the belt. As noted by Rodgers (1970, p. 131), the folding must represent a very great shortening of the original basin across the strike such that the present width of the belt is only a relatively small fraction of its original width. No sign of the floor on which the Ordovician to Lower Devonian sediments were laid down is visible anywhere in the belt, and Rodgers (1970) suggested that if the floor was shortened with the sedimentary cover it must have been non-sialic and presumably was disposed of downward [by subduction]. Ordovician ocean crust of probable Lower Ordovician age has been recognized, however, as basement to the folded and cleaved Silurian-Lower Devonian strata of the Chaleur Bay synclinorium southeast of the Aroostook-Matapedia anticlinorium in northern New Brunswick (Stringer, 1975; Rast *et al.*, 1976; Pajari *et al.*, 1977; Rast and Stringer, 1980). Shortening of the cover rocks by decollement on the underlying basement has been proposed (Rodgers, 1970, p. 132; Stringer, 1975).

The folding and cleavage of Silurian-Lower Devonian rocks in the Appalachian/Caledonian orogen have been attributed to late Silurian and Devonian deformation resulting from continental collision during closure of the Proto-Atlantic (Iapetus) Ocean (Dewey and Kidd, 1974), and in southern Scotland the deformation has been related directly to subduction during the Silurian (Leggett *et al.*, 1979; Stringer and Treagus, 1980) along the northwest margin of the Iapetus Ocean (Cocks *et al.*, 1980). In the Canadian Appalachians, however, Williams (1979) has argued that the Iapetus Ocean closed during the Taconian (Ordovician) orogeny and that the Acadian orogeny was intraplate, subsequent to the closure of the Iapetus Ocean. In New England, Robinson and Hall (1980) have suggested that the Acadian orogeny was a result of Siluro-Devonian convergence between adjoining continental plates, because closure of an ocean cannot be proven and it is possible that the tectonic features formed through development of a west-

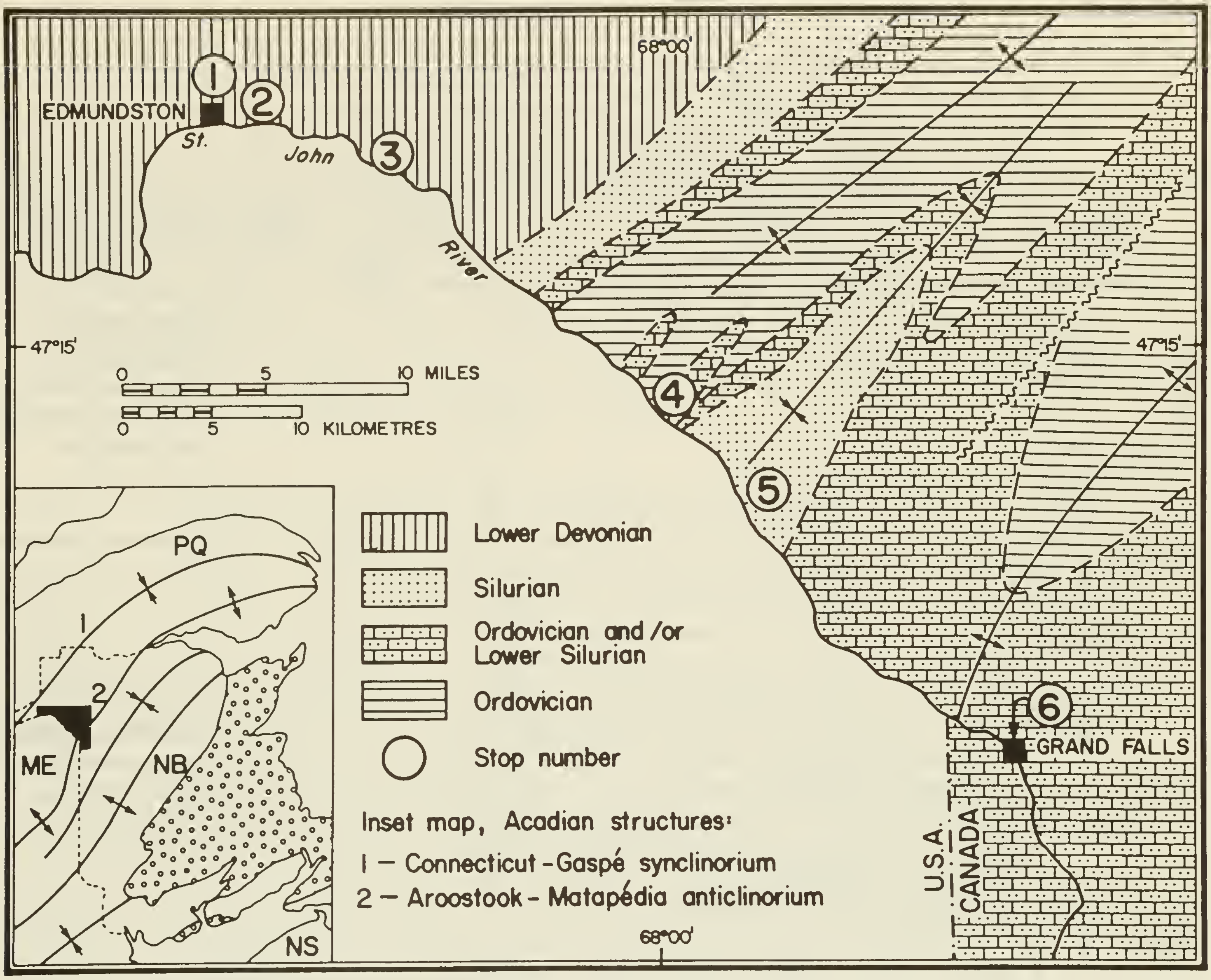


Figure 1. Generalized geological map of the Edmundston - Grand falls area, New Brunswick (based on St. Peter, 1977, fig. 2). Inset map shows Acadian (Devonian) anticlinoria and synclinoria in New Brunswick and adjacent Maine and Quebec (based on Rast and Stringer, 1974), the Carboniferous cover (ornament), and the location of the trip area.

dipping subduction zone within a former single continental plate. Whatever the cause, the folding and cleavage attest to very significant shortening during the Acadian (northern Appalachians) and Erian (Ireland to Scandinavia) orogeny. In the Edmundston - Grand Falls area, Middle to Upper Ordovician as well as Silurian-Lower Devonian sediments were involved in the Acadian orogeny. Taconian deformation is lacking in the Carys Mills Formation; some folding in the underlying unnamed unit may be Taconian (Hamilton-Smith, 1969, 1970).

	SERIES	Siegas Hamilton - Smith, 1970	AROOST. – MAT. ANTICLINORIUM St. Peter, 1977 EAST	AROOST. – MAT. ANTICLINORIUM St. Peter, 1977 WEST
LOWER DEVONIAN	Emsian			**Temiscouata Formation** siltstone, slate, arkose, greywacke, conglomerate
LOWER DEVONIAN	Sieg.			
LOWER DEVONIAN	Ged.			
SILURIAN	Ludlow	? —— ? Perham Formation: **Upper Member** shale, siltstone, minor sandstone		**Perham Formation** slate, sandstone, lithic wacke, limestone
SILURIAN	Wenlock	Perham Formation: **Lower Member** calcareous slate, minor siltstone		
SILURIAN	Landovery	Perham Formation: Lower Member (cont.)	**Upsalquitch Fm.** siltstone, sandstone, greywacke	
SILURIAN	Landovery	**Siegas Formation** sandstone, slate, limestone	**Matapedia Group** limestone, shale	**Matapedia Group** (cont.)
ORDOVICIAN		**Carys Mills Fm.** limestone, slate	**Matapedia Group** (cont.)	**Matapedia Group** (cont.)
ORDOVICIAN		**Unnamed Unit** slate, shale, sandstone	**Grog Brook Group** argillite, sandstone, greywacke; minor conglomerate, limestone	**Grog Brook Group** (cont.)

Table 1 Lithology and stratigraphic correlation of Ordovician to Lower Devonain formations in the Edmunston-Grand Falls area, New Brunswick.

Folding and cleavage

The tight upright Acadian folds in the Middle Ordovician-Lower Devonian sediments of the Edmundston - Grand Falls area trend NE-SW and are similar in style to Acadian folds throughout much of New Brunswick and adjacent regions of the northern Appalachians. Sporadic to well developed cleavage associated with the folds is persistently steep or vertical. The folds and cleavage have been designated as F_1 and S_1, and the cleavage has been described as axial planar to the folds (St. Peter, 1977). Stereographic plots of bedding and cleavage (Hamilton-Smith, 1970, figs. 10-14) suggest, however, that the cleavage strikes a few degrees clockwise of the strike of the fold axial surfaces. Cleavage noncoplanar with fold axial surfaces is a widespread feature of Acadian deformation in the northern Appalachians (Stringer, 1975).

The S_1 cleavage, recorded as a slaty or fracture cleavage by St. Peter (1977), is formed by parallel or anastomosing partings, spaced at about 10 mm intervals in sandstone beds and much more closely in siltstone and mudstone (shale) beds. In thin sections of siltstones and mudstones at the hinges of F_1 folds, the mesoscopic S_1 cleavage partings are seen as dark films (*c.* 0.005 mm thick) made of fine-grained white mica, opaque minerals and irresolvable material, in which the micas are aligned subparallel or parallel to the cleavage direction. In the microlithons (*c.* 0.04 mm thick) between the cleavage films, fine-grained white mica, quartz and calcite grains commonly show no obvious preferred orientation, apart from occasional parallelism with bedding. Diagenetic chlorite grains within the microlithons often display mineral cleavage planes oriented perpendicular or at a high angle to the S_1 cleavage films, and muscovite laths are occasionally intergrown with the chlorite grains parallel to the mineral cleavage of the chlorite host. Compression within the microlithons perpendicular to the S_1 cleavage is indicated by crenulation of the chlorite mineral cleavages and the intergrown muscovite laths. Where thin calcareous or quartzose siltstone beds are present within the folded mudstones, the S_1 cleavage films converge towards re-entrants in the silty layers formed by buckles and by reverse microfaults (Figs. 2 and 4). The S_1 cleavage films correspond to pressure solution planes (Durney, 1972; Williams, 1972; Gray, 1979; Stephens *et al.*, 1979), and the cleavage should therefore be described as a pressure solution cleavage. The pressure solution cleavage films represent a significant component of the shortening normal to the cleavage direction (Gray, 1979, pp. 114-7).

Evidence for the origin of the S_1 cleavage films by pressure solution is provided by a progressive development of microstructures (Gray, 1979, fig. 3) which can be recognized in thin sections of the S_1 cleavage from the hinges of F_1 folds in laminated silty mudstones in the Edmundston - Grand Falls area (Fig. 3). Shortening in the mudstone is represented by uniformly and closely spaced pressure solution S_1 cleavage films, and by compression of the intervening microlithons indicated by the crenulated chlorite grains. Shortening in the interbedded thin silty layers, in which pressure solution films commonly are lacking, occurred by symmetric to asymmetric buckling concomitant with development of the pressure solution films in the mudstone. Adjacent asymmetric buckle folds may

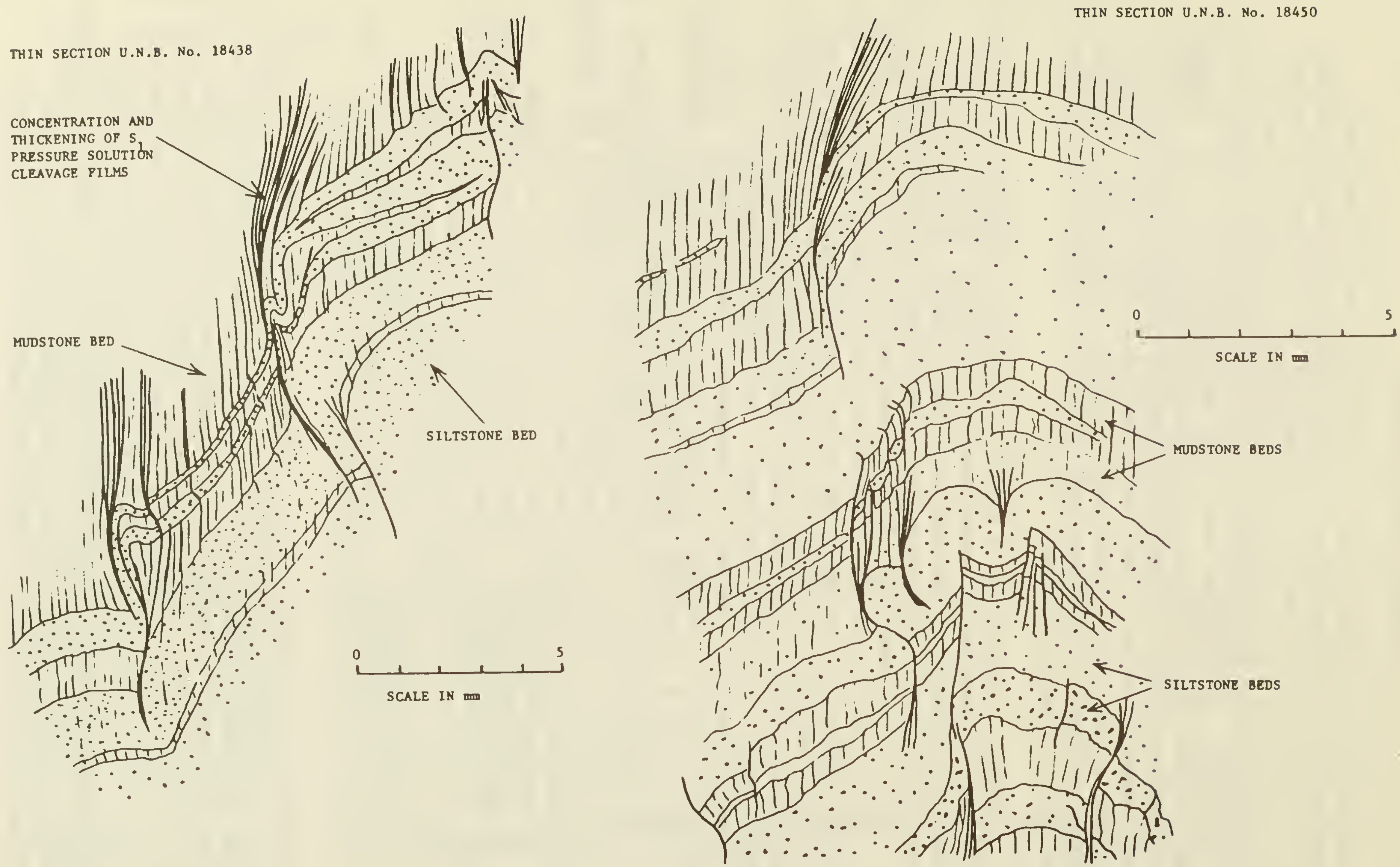


Figure 2. Concentrated and thickened S_1 pressure solution cleavage films in mudstone beds converge upon the short limbs of asymmetric microfolds in thin siltstone beds. Silurian Perham Formation, St. Leonard, New Brunswick (Stop 5).

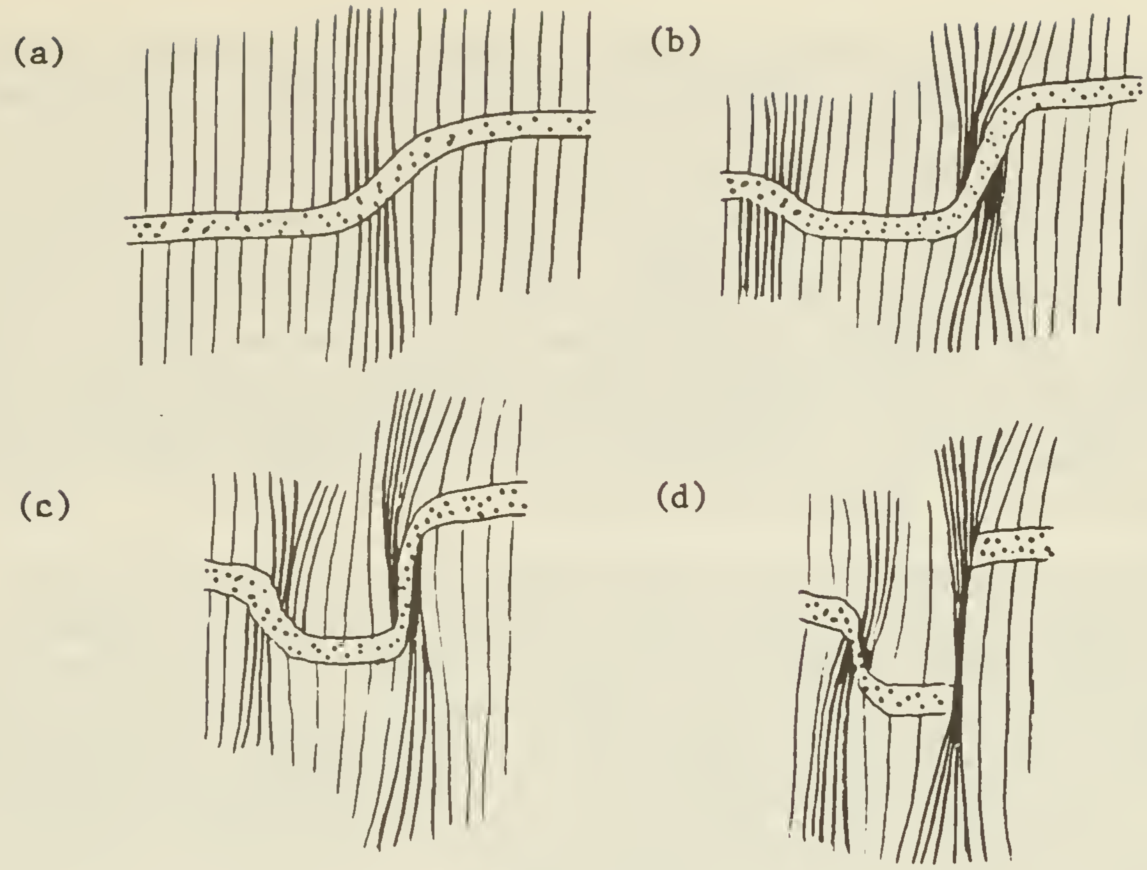
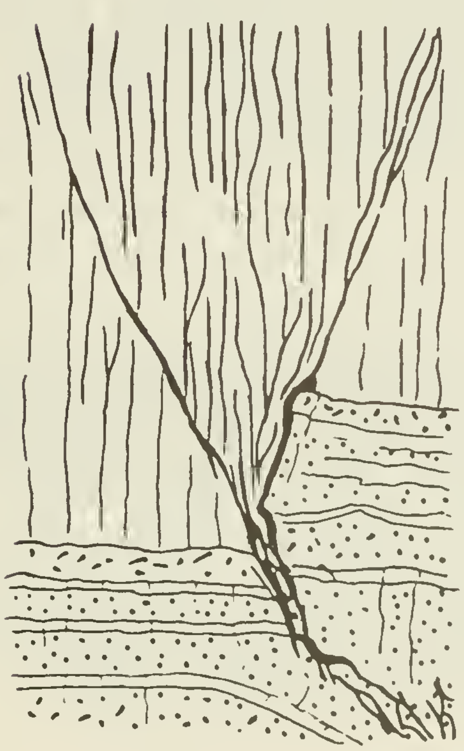


Figure 3. Schematic diagram illustrating the progressive development of microstructures in laminated silty mudstone during pressure solution on S_1 cleavage planes in the mudstone concomitant with asymmetric buckling of a thin silty layer. (a) Evenly spaced S_1 pressure solution films in the mudstone show slight concentration and thickening adjacent to short limb of gentle asymmetric microfold in the silty layer. (b) and (c) Progressive concentration, thickening and convergence of S_1 pressure solution films against the rotating and partly dissolved silty layer in the short limb, and development of a second asymmetric microfold with opposite vergence. (d) Complete solution of short limb produces apparent offset of silty layer along thickly concentrated S_1 pressure solution films.



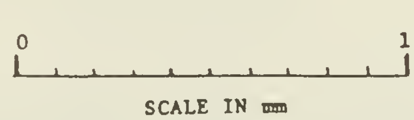


Figure 4. Divergent pressure solution films associated with reverse micro-faulting of a siltstone bed are superimposed upon uniformly spaced S_1 pressure solution films in the mudstone bed.

show opposing vergence. Pressure solution films in the mudstone are more closely spaced and slightly thicker near the short limbs of the asymmetric folds, indicating more intense solution of the microlithons (Fig. 3a). With progressive rotation of the short limbs, the pressure solution films in the mudstone become more concentrated, converging towards each side of the short limb (Fig. 3b), and the silty layer is progressively dissolved (Fig. 3c). The final stage is marked by loss of the short limb and the development of a continuous zone of concentrated pressure solution films along which the silty layer appears offset, resembling a microfault (Fig. 3d). The different stages of microstructural development can often be traced across several silty layers within a single thin section, from gentle asymmetric microfold to apparent microfault.

Shortening of the thin silty layers by actual microfaulting is indicated in places by low to high angle reverse microfaults, commonly associated with the short limbs of asymmetric microfolds. Concentrations of pressure solution films which diverge away from the reverse fault in the silty layer into the adjacent mudstone may be superimposed upon uniformly spaced pressure solution films formed in the mudstone prior to the microfaulting (Fig. 4). Thus polyphase pressure solution microstructures may be produced during a single phase of shortening.

Slump folding

Recumbent folds which pre-date the F_1 folding and the S_1 cleavage are common in the Ordovician-Lower Devonian sediments of the Edmundston - Grand Falls area (Stops 2 and 6). Acadian folding of the earlier folds is prominent in the Lower Devonian Temiscouata Formation (Stop 3), and has been described in the Lower Silurian Siegas Formation (Hamilton-Smith, 1970, pp. 29-30). The earlier folds exhibit no constancy in scale, style or orientation, and lack axial plane cleavage (St. Peter, 1977), and have been interpreted as slump folds in unconsolidated water-laden sediments. Large scale recumbent pre-F_1 folds indicated by inverted bedding in the Upper Ordovician-Lower Silurian Carys Mills Formation in the Woodstock area (Rast *cum al.*, 1980) 110 km south of Grand Falls have been interpreted by Rast as soft-sediment deformation features due to submarine slip, although Rast noted (*ibid.*, p. 7) that it is very strange that no soft sediment brecciation is associated with the large scale structures.

Sedimentology

Apart from the absence of late Silurian to early Devonian (Pridolian to Gedinnian) strata, which St. Peter (1977) interprets as a Ludlovian to Gedinnian disconformity, sedimentation within the area between Edmundston and Grand Falls was essentially continuous from at least Middle Ordovician (zone of *Nemagraptus gracilis*) to Lower Devonian (Emsian) time. This sedimentation occurred within a narrow northeast/southwest elongate trough extending from Gaspé through New Brunswick and into Maine and termed the Central Clastic Belt and/or Aroostook-Matapedia Carbonate Belt by Ayrton *et al.* (1969). Strata in this belt have been assigned various group and/or formational names at different places along the belt.

Within the Edmundston and Grand Falls section of the belt, relatively few and detailed sedimentological analyses have thus far been undertaken, notable exceptions being the studies of Hamilton-Smith (1970, 1971a, 1971b) in the Siegas area and St. Peter (1977) in the Edmundston-Grand River area. It is apparent from these studies that the Middle Ordovician-Lower Devonian strata were deposited in a deep-water trough, within which a series of isolated uplifted areas provided sedimentary detritus. Evidence of deep-water deposition is not only provided by detailed analysis of sedimentary lithofacies and depositional mechanisms but also by the existence of a deep-water *Nereites* ichnofacies recently described by Pickerill (1980) immediately to the northeast in the Matapedia district in northern New Brunswick.

Sedimentological aspects emphasized on this excursion will be directed essentially toward the Late Ordovician-early Silurian Carys Mills (Stop 6) and the early Llandovery Siegas (Stop 4) Formations (Table 1). The Siegas Formation is in part clearly erosive into the underlying Carys Mills Formation, the estimated depth of erosion being in the order of *c.* 25-50 m (Hamilton-Smith, 1971b). Proximal turbidites with partial and/or more complete Bouma sequences and well-developed resedimented limestone conglomerates characterize these erosive fills. Associated massive and structureless sandstone beds most probably represent deposition from grain and/or fluidized flows. Proximal-distal relationships and palaeocurrent analysis undertaken by Hamilton-Smith (*ibid.*) suggest derivation from the north and north-west from an isolated topographic high. The Siegas Formation was thus a localized channel sequence developed within the Carys Mills Formation. More distal lithofacies of the former are undoubtedly lateral facies equivalents of the latter.

The Carys Mills Formation and lateral equivalents throughout the belt (*e.g.* Smyrna Mills Formation, Matapedia Group, *etc.*) consist essentially of thinly interbedded calcareous argillites and argillaceous calcitic and ankeritic limestones with thin and randomly developed graded calcarenites with a substantial quartz component. Differential solution has commonly etched the more limy beds to a greater extent so that the rocks have a markedly ribbed appearance and are commonly referred to as 'ribbon limestones' (Ayrton *et al.*, 1969). Previous authors (*e.g.* Ayrton *et al.*, 1969; St. Peter, 1977) have interpreted the Carys Mills Formation as having resulted from deposition by turbidity currents in a distal palaeoenvironment. We believe, however, that this is an oversimplification and that whilst some units are suggestive of deposition from turbidity currents, the majority of units are not. The thinly bedded calcarenites exhibit partial Bouma sequences, particularly T_a and T_{a-b} sequences, are often erosive and contain broken and abraded shallow-water benthic marine fossils. We believe these units to be the result of deposition by turbidity currents. The thinly bedded calcareous argillites and argillaceous calcitic and ankeritic limestones are, however, considered to result from deposition by hemipelagic and normal bottom-following contour currents *viz:*- contourites. Though the differentiation of contourites and turbidites in the geologic record is extremely difficult and often hazardous because of the lack of suitable distinguishing criteria (Bouma and Hollister, 1973), the following observations are suggestive of deposition by deep thermohaline boundary (contour) currents which paralleled the ancient palaeoslope.

(i) The presence of abundant intraformational slump horizons within the Carys Mills Formation together with minor resedimented debris flow and olistostromal horizons. Such an association is more consistent with slope (both modern and ancient) environments rather than distal or overbank turbidite associations.

(ii) The widespread occurrence of similar facies which parallel the presently exposed margins of the trough.

(iii) The presence of distinctive submarine channel lithofacies which cut the regional strike and palaeocurrent (*e.g.* the Siegas Formation) of the Carys Mills Formation.

(iv) The presence of a trace-fossil assemblage more consistent with slope deposition rather than deep bathyal or abyssal palaeoenvironmental conditions (*e.g.* amongst others, vertical burrows which cross-cut successive units, *Diplichnites*, *Fucusopsis*, *Gyrochorte* and spreiten-bearing forms).

(v) The presence of lenticular and irregular, commonly bioturbated, horizons comparable to the 'muddy contourites' of Stow and Lovell (1979).

It is therefore suggested that the Carys Mills Formation represents a succession of contourites and hemipelagic deposits which include randomly and thinly developed turbidites. In modern regimes this association is most consistently developed in continental rise environments (Stow and Lovell, 1979). Nevertheless, as outlined above, evidence in the Carys Mills Formation suggests that such an association may be equally as common in an ancient slope environment.

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Itinerary

Assembly point is in the parking lot of Keddy's Motor Inn, Presque Isle. Starting time 8:00 AM (Eastern Standard Time). Upon leaving the parking lot, drive out of Presque Isle and follow Route 1 for 60 miles (96 km) north via Van Buren and Madawaska to Edmundston. Proceed through Canada Customs and Immigration at the international border between Madawaska, Maine and Edmundston, New Brunswick, and drive 2 miles (3.2 km) north through Edmundston East to the Edmundston Motel on Route 2 (Trans-Canada Highway).

Mileage	Km	
00.0	00.0	Stop 1. Park on southwest side of Trans-Canada Highway (Route 2) at front of Edmundston Motel, Edmundston. Cross highway to 100 m long road section. Lower Devonian Temiscouata Formation. Dark grey laminated shaly siltstones are deformed by symmetrical NE-SW trending Acadian open folds (half-wavelength 50 m) and subvertical S_1 pressure solution cleavage striking 052°. Cleavage/bedding intersections plunge NE between 10° and 40°. At the northwest end of the road section, small scale (0.5 cm) load casts in thinly bedded fine grained sandstone interbeds in the hinge of a syncline indicate that beds are the right way up. About half way along the road section, spaced composition banding parallel to vertical cleavage in gently inclined beds indicates differential mineral concentration along cleavage planes by pressure solution. Return to vehicles and continue east on Route 2.
2.3	3.7	Stop 2. Park on south side of highway at roadside outcrop 30 m west of overhead power transmission lines. Slump structures in Temiscouata Formation. At the west end of the outcrop, tight minor recumbent slump folds are exposed at the top of the rock faces within gently inclined bedding. At the east end of the outcrop, a 1 m thick horizon of irregular slump structures dips SE within the limb of an upright NE-SW trending Acadian fold with subvertical S_1 pressure solution cleavage which strikes 053° and cuts through the slump structures. In places, a weak second cleavage, S_2, is present at a slight angle to the S_1 cleavage. Return to vehicles and continue east on Route 2.
5.0	8.0	St. Basile
7.3	11.7	Stop 3. Park on south side of highway by the Weigh Station sign. Cross highway to outcrop on north side of road.

Mileage	Km	
		Folded larger scale recumbent slump fold, Temiscouata Formation. A tight recumbent slump fold in dark grey laminated shaly siltstone exposed for 20 m along its axial surface is folded around the hinge of a NE-SW trending Acadian anticline. S_1 pressure solution cleavage inclined steeply NW cuts through both limbs of the slump fold. Sedimentary structures in the core of the anticline indicate that bedding in the lower limb of the slump fold is inverted. There is no fabric parallel to the axial surface of the slump fold. Minor isoclinal slump folds verging southeast are discernible on the upper limb of the larger scale slump fold near the east end of the outcrop.
		Return to vehicles and proceed east on Route 2.
11.3	18.2	Cross bridge over Green River (Riviere Verte).
17.3	27.8	Ste. Anne de Madawaska
19.9	32.0	Turn left off Route 2, follow gravel road round back of house and proceed east on old paved road.
20.2	32.5	Stop 4. Park on road near gates to Siegas Quarry. Walk 300 m north along road into quarry.
		Lower Silurian Siegas Formation. The Siegas Quarry is located on the northwest flank of the Aroostook-Matapedia Carbonate Belt of Ayrton *et al.* (1969), the most prominent large structure of northeastern Maine and northwestern New Brunswick during the Taconic orogeny (Hamilton-Smith, 1971a). Although borderlands on both sides of this belt were deformed, uplifted and eroded during the Taconic orogeny, the Aroostook-Matapedia Carbonate Belt continuously received sediment so that no unconformity of any regional significance was developed within this belt during Middle Ordovician-Late Silurian times. The characteristic rocks of this part of the belt are known regionally as the Carys Mills Formation, a succession of calcareous thinly bedded flysch containing graptolites of Middle Ordovician (*Orthograptus truncatus* var. *intermedius*) to early middle Llandovery (*Monograptus communis*) age. The Siegas Quarry, however, exposes rocks of a locally developed clastic facies within this more regionally developed calcareous flysch known as the Siegas Formation. This formation ranges in thickness from *c.* 105-240 m in the Siegas district and thins to zero within 10 km to the south (Hamilton-Smith, 1971a).
		The Siegas Quarry represents the principal reference section of the Siegas Formation (Hamilton-Smith, 1970) and exhibits

Mileage	Km	

excellent exposures of limestone conglomerates, sandstones, siltstones and shales. Fragmentary brachiopod genera include *Stricklandia*, *Plectothyrella*, *Leangella*, *Mendacella*, *Eoplectodonta*, *Dalmanella* and *Protatrypa* and attest to an early Llandovery age. These and additional faunas are listed in Ayrton *et al.* (1969).

The limestone-conglomerates and sandstones exhibit features indicative of an origin by turbidity current grain support mechanisms. These beds, which range in thickness from 4 cm - 8 m, show excellently developed clast imbrication, partial and more complete Bouma sequences and a whole variety of sole structures, such as gutter casts, prod, bounce and other tool markings, flute casts, load casts, ripple marks and dewatering features. Detailed palaeocurrent analysis by Hamilton-Smith (1971a) indicated a provenance from the north and northwest, which he suggested to be an isolated relatively discrete uplift similar to others previously described in northeastern Maine by Pavlides *et al.* (1964). The interbedded siltstones and shales are generally 1-100 cm thick and exhibit parallel or more rarely cross-laminations. They represent material reworked and/or deposited by normal bottom marine currents. Organic activity is evidenced by the obscure trails preserved on the upper surfaces of some siltstones and shale beds as well as the more recognizable ichnogenera *Chondrites*, *Planolites*, *Fucusopsis* and *Diplichnites*. Comparison of the Siegas Facies association with similarly described ancient analogues suggests deposition in a submarine channel or slope/base of slope environment. The localized development of the formation suggests that a channel is probably more realistic.

More detailed and complete descriptions of the Siegas Formation lithofacies and regional relationships may be obtained in Hamilton-Smith (1969, 1970, 1971a, 1971b).

Return to vehicles and continue east along old paved road.

20.5 33.0 Turn left onto Route 2 and continue eastward.

25.0 40.3 Stop 5. Park on south side of highway at roadside outcrop 600 m west of Route 2/Route 17 interchange, St. Leonard.

Silurian Perham Formation. A NE-SW trending Acadian syncline plunging gently SW at the east end of the outcrop deforms slightly calcareous grey laminated silty mudstones. Intense small-scale buckling of thin (1-5 mm) siltstone beds indicates considerable shortening concomitant with pressure solution on the S_1 cleavage planes in the mudstone beds (Fig. 2). The S_1 cleavage dips steeply SE. Convergent cleavage refraction is prominent in the thicker (3 cm) silty beds.

Mileage	Km	
		Return to vehicles and continue east on Route 2.
32.6	52.5	Cross bridge over C.N.R. tracks.
36.1	58.1	Turn right off Route 2 at interchange exit for Grand Falls. Cross bridge over Route 2 and follow road down to Grand Falls.
38.0	61.2	Stop 6. Turn right off road into parking area of Falls View Motel, Grand Falls. Clamber down bank to extensive outcrop at confluence of Saint John River and Little River.

Upper Ordovician-Lower Silurian Carys Mills Formation, Aroostook-Matapedia anticlinorium. Beds striking NE-SW and dipping steeply SE young towards the southeast and are intersected by S_1 pressure solution cleavage which strikes ENE-WSW and dips 45-85° NNW. The *c.* 100 m thickness of beds exposed includes numerous horizons of spectacular intraformational slump folding. In places, the axes of tight slump folds and convolute structures plunge steeply SE at a maximum down the dip of the beds, but most of the slump folds are variably oriented.

The majority of the beds exposed here are composed of the more typical 'ribbon limestones' of the Carys Mills Formation. The argillaceous calcitic and ankeritic limestones are internally quite variable, some exhibiting grading, some parallel lamination, some cross-lamination, whilst others exhibit bioturbation or appear to be generally structureless. The majority of beds are laterally continuous whilst others are lenticular and irregular. Associated thin and graded calcarenites may also be observed, many of which have been completely dismembered due to *in situ* soft-sediment deformation. Without doubt, however, the most obvious soft-sediment deformation features are the spectacularly developed intraformational slump fold horizons, some of which are 2 m in thickness. At the southeastern edge of the exposure occurs an enigmatic debris flow or olistostromal horizon. The presence of this and the slump folds attest to the presence of a slope during deposition of the ribbon limestones.

Return to vehicles and drive out of motel car park, turning right onto the road.

38.2	61.5	Turn right (south) following sign for Grand Falls Centre and Fredericton, crossing bridge over the Saint John River. Continue south along Broadway through Grand Falls centre.
38.8	62.4	At south end of Broadway turn left, following sign for Route 2 East. Follow road up the hill out of Grand Falls.

Mileage	Km	
41.1	66.2	Turn left onto Route 2 at Grand Falls Portage, following sign for Fredericton, Route 2 East. Proceed south on Route 2.
54.0	86.4	<u>Stop 7</u> (optional). East side of highway (Route 2), north of Four Falls. Pre-Acadian (Silurian?) dykes in 'ribbon limestones' of the Upper Ordovician-Lower Silurian Carys Mills Formation. Return to vehicles and continue south on Route 2.
59.8	95.7	Turn right off Route 2 at Perth-Andover interchange onto Route 19 (N.B.)/Route 167 (Maine) and drive west to Fort Fairfield, passing through U.S. Immigration and Customs at the international border. Follow Route 167 from Fort Fairfield to Presque Isle. The distance back to Presque Isle from Perth-Andover is 18 miles (29 km). End of field trip.