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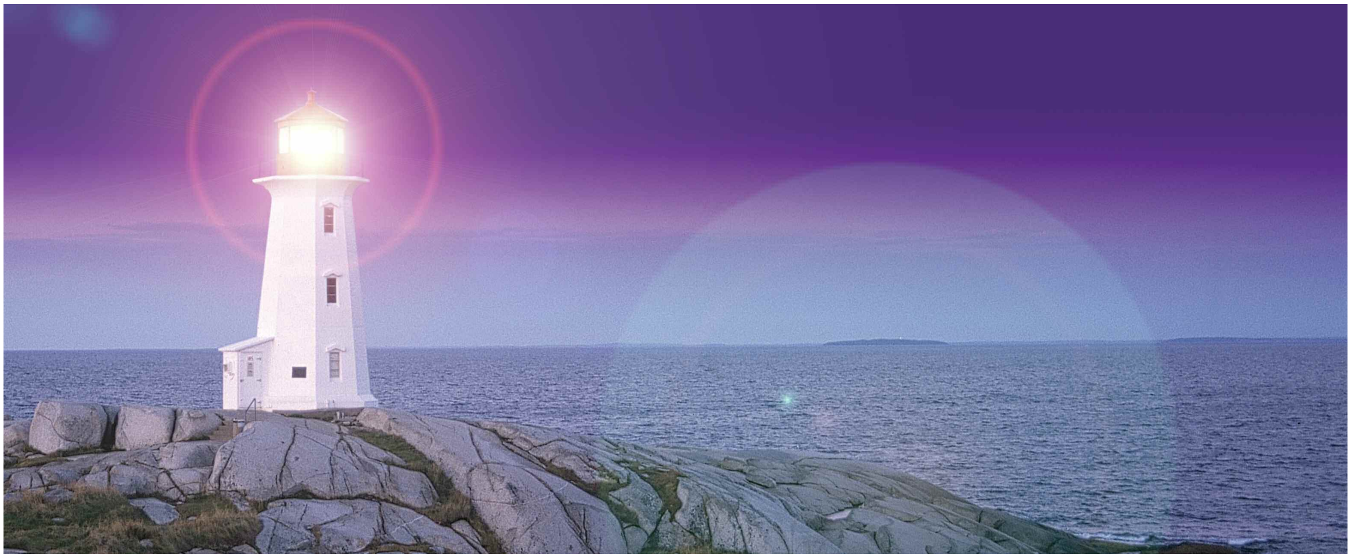

Field Trip B6

The macrotidal environment of the Minas Basin, Nova Scotia: sedimentology, morphology, and human impact

Ian Spooner, Andrew MacRae,
and Danika van Proosdij

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THE MACROTIDAL ENVIRONMENT OF THE MINAS BASIN, NOVA SCOTIA: SEDIMENTOOGY, MORPHOLOGY, AND HUMAN IMPACT

by

Ian Spooner, Andrew MacRae, Danika van Proosdij, and Gary Yeo

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The macrotidal environment of the Minas Basin, Nova Scotia: sedimentology, morphology, and human impact

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The locals also tell stories of people who have become stuck in the mud and drowned. Consequently, CAUTION MUST BE EXERCISED AT ALL TIMES. Please stay with the group and listen to the leader's instructions. Do not wander off on your own!

With respect to the mud, the rule of thumb is that if you sink in deeper than mid-calf, return to solid ground as quickly as possible. DO NOT STOP MOVING as this will allow the mud to "freeze", trapping you more firmly.

THE AUTHORS ACCEPT NO RESPONSIBILITY FOR INJURIES OR DEATH SUSTAINED BY ANY USER OF THE GUIDEBOOK.

SUMMARY

The Bay of Fundy is an elongate, structurally-controlled basin situated on the east coast of Canada between the provinces of New Brunswick and Nova Scotia. It is widely known and frequently cited for its very large tidal range, which averages 12.0 m. Most of the floor of the outer Bay of Fundy is presently non-depositional or erosional as a result of the strong tidal currents and the minimal input of sediment from terrestrial sources. By contrast, the two major estuaries at the head of the Bay (the northern Chignecto Bay arm and the eastern Minas Basin-Cobequeid Bay arm) are experiencing rapid accumulation of sediment. In these two arms Holocene tidal deposits are in places more than 10m thick.

This field trip will focus on the sedimentology, morphology, and natural history of the Windsor Bay area with emphasis on the Cornwallis and Avon River Estuaries. This region is one of the more thoroughly studied macrotidal areas in the world sedimentologically. This work has covered virtually all aspects of the sedimentation processes and deposit characteristics. As a result, this field trip will focus on an overview of tidal deposits and the response of the system to changing sea levels and tidal ranges since deglaciation. We will also visit some historic sites in the region and explore how the natural environment has influenced human activity in the region.

Disclaimer: This guide book contains, in part, an abbreviation of material originally presented in the Geological Association of Canada-Mineralogical Association of Canada (GAC-MAC) Field Excursion A-8: Guidebook (1992) and in the Geological Society of America(GSA) – Atlantic Geoscience Society (AGS) Field Trip 401 Guidebook (2003) both of which are available through many library and private collections. They can also be obtained by contacting:

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Please refer to the above volume for a much more thorough treatment of many of the topics discussed herein. Access information to many of the sites can also be found in the 1992 publication.

1.0 INTRODUCTION: SEDIMENTOLOGY OF THE CORNWALLIS RIVER ESTUARY

1.1 SURFICIAL GEOLOGY AND GEOMORPHOLOGY

The Cornwallis River estuary lies at the southwestern corner of the Minas Basin, and is the focus of drainage from the eastern part of the Annapolis Valley (Fig. 1,2). The Annapolis Valley is bounded on the north by the North Mountain cuesta that is capped by Triassic-Jurassic basalt, and on the south by a highland area called the South Mountain that is underlain by Paleozoic metasedimentary and granitic rocks. The valley floor is underlain by red fluvial sandstones of the Triassic Wolfville Formation, and by the conformably overlying fluvial and lacustrine mudstones of the Blomidon Formation (Fig. 3a). The Wolfville sandstone is exposed in low cliffs along the shore of the Cornwallis River estuary. Unconsolidated, surficial sediments include red silty till, outwash sands and muds, and the recent tidal deposits.

The Cornwallis River estuary is a convergent (trumpet- shaped) estuary. Its mouth lies between Kingsport and Long Island-Evangeline Beach, while the head of tide is about half a kilometre upriver from Kentville. It is strongly macrotidal, having a spring tide range in the outer estuary of about 15 m, and a neap tide range of approximately 9 m (Fig. 3b). Average salinity decreases headward, from about 29‰ at the mouth to less than 0.1 ‰ at the Kentville bridge. In the outer estuary, higher salinities are observed along the south shore, where the flood tide is strongest (Daborn and Pennachetti, 1979). The total volume of water in the estuary, as estimated from bathymetry (Yeo; in Daborn, 1991), is about 138 x 106 m^3. The mixing index (the volumetric ratio of fresh water input during a half-tidal period to marine water entering during a flood tide; Schubel, 1971) is estimated to be 0.004 (Dickinson, 1991). This is well within the range for well-mixed, Type C (Pritchard in Schubel, 1971) estuaries.

The Cornwallis estuary is dominated by muddy sediments (Fig. 4). The outer estuary (i.e., seaward of Wolfville; Figs. 3, 4), in particular, is characterized by broad mudflats instead of the erosional foreshores and elongate sand bars which are so abundant in Cobequid Bay (Fig. 2). The chief reason for the difference is the nature of the sediment source; because of the extensive outcrops of muddy Blomidon Formation at Cape Blomidon to the north, the Cornwallis estuary receives little sand. The abundance of mud in turn causes this area to be more productive biologically than Cobequid Bay, and organisms have a much greater influence on sedimentation and erosion, especially in the outer estuary. Partly because of the abundant mud, there has been little research done on the sedimentology of the Cornwallis estuary.

1.2 THE INNER CORNWALLIS ESTUARY

The Cornwallis River is tidal to a point about 0.5 kilometres upriver from Kentville. The channel from Wolfville to the head of tide is relatively narrow, has steep banks, and lacks the extensive tidal flats characteristic of the outer estuary. The width to depth ratio is only on the order of 10-20 through the first 10-15 km below the tidal limit, and then increases dramatically beyond this. The bankfull capacity of the inner estuary above the Port Williams bridge (Stop 4) is about 8 x 10^6 m^3 of which 97.5% is tidal. Hence, average tidal discharge is about 360 cubic metres per second.

Suspended sediment concentration in the inner estuary ranges up to 5 g/1 (Daborn and Pennachetti. 1979) with a turbidity maximum located in the vicinity of the town of New Minas. In contrast suspended sediment concentration at the mouth of the outer estuary is about 10 mg/1 or less. Salinity ranges from 0 ‰ at Kentville to 30 ‰ at Wolfville, while water temperature is variable. Due to the strong currents, high turbidity, low average salinity, and variable temperature within the inner estuary, very few organisms live here except in the salt marshes. This is in marked contrast to the high biological productivity of the outer estuary. Benthic diatoms and colloform bacteria are abundant however (Dickinson, 1991); faecal colloform numbers, for example, are typically above 200 per ml (except in the winter!).

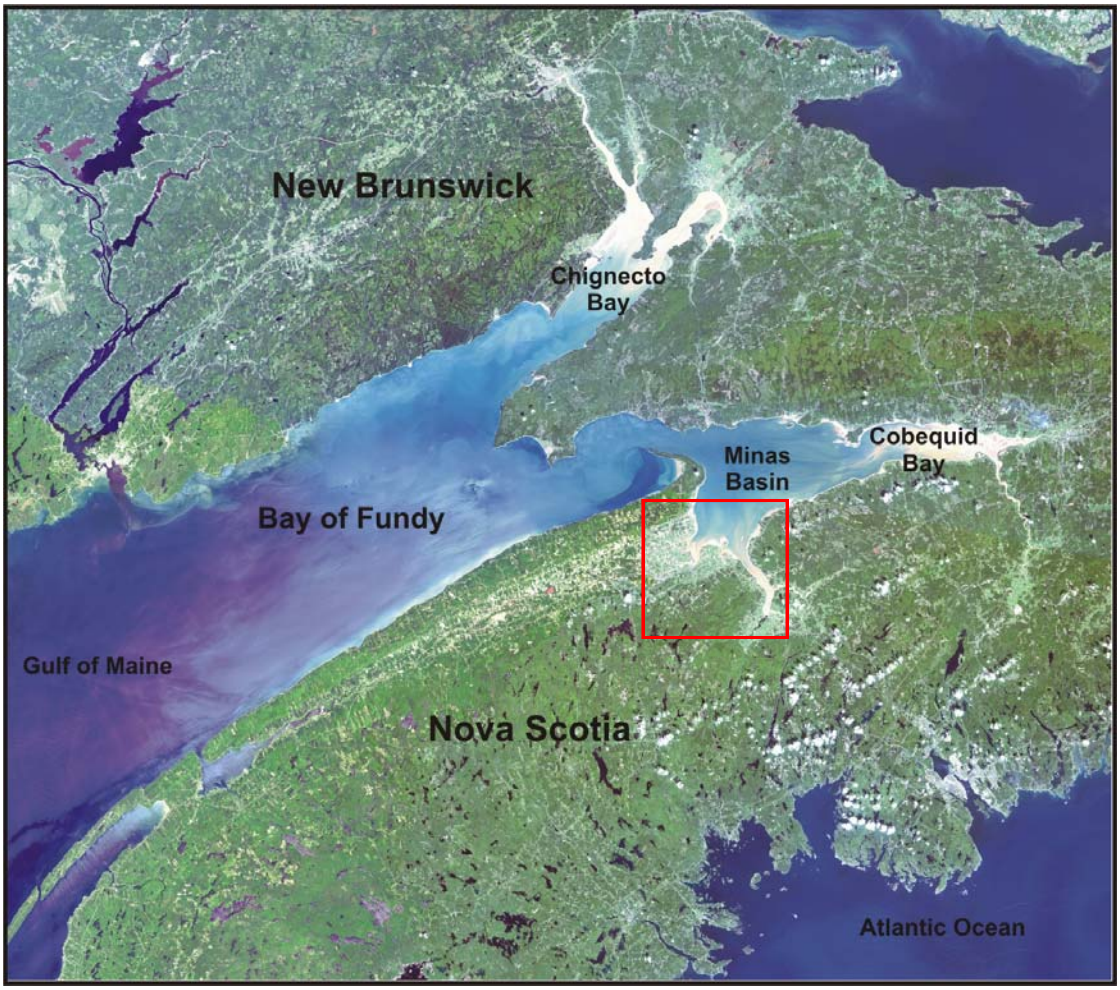

***Figure 1**. Landsat image of the Bay of Fundy. Red box indicates general geographical area of field trip.*

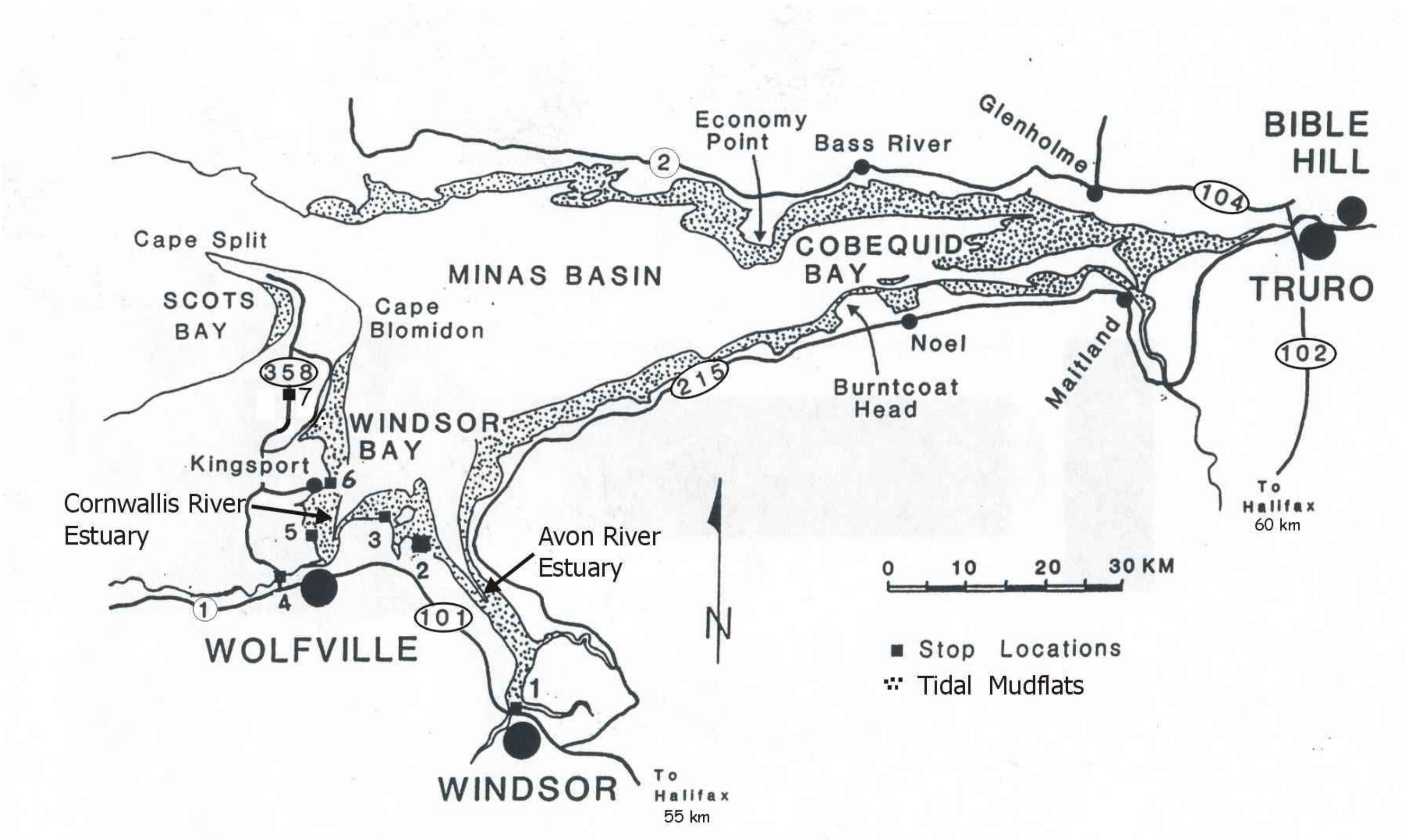

Figure 2. *Map of the Minas Basin-Cobequid Bay-Salmon River area showing the location of the stops to be visited on the map.*

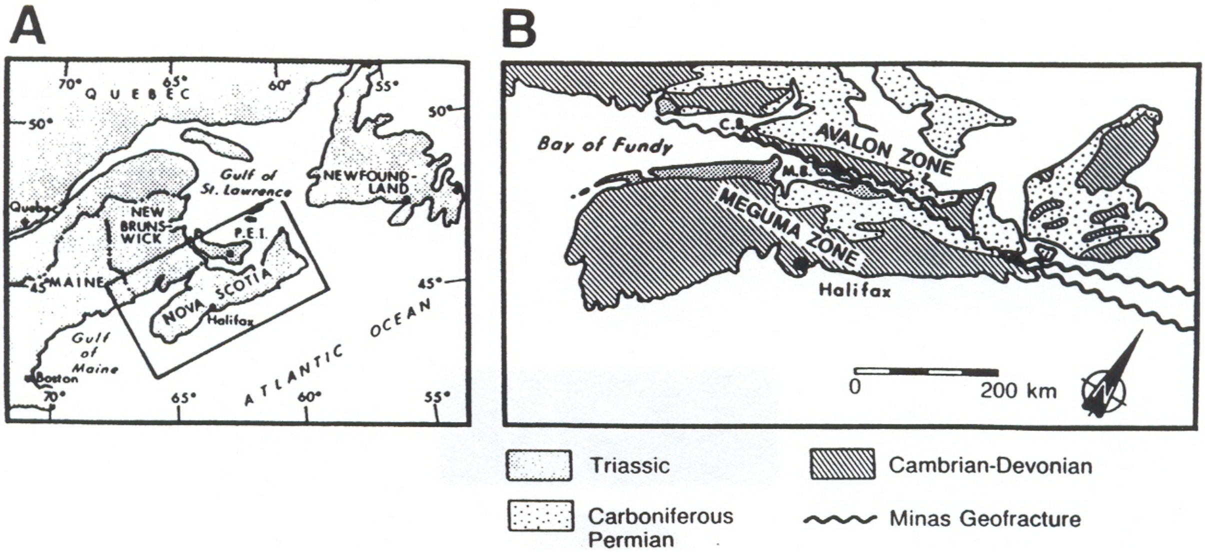

Figure 3a. *A: Location map of eastern Canada. B: Geological and location map of the Bay of Fundy region. M.B. Minas Basin; C.B. Chignecto Bay.*

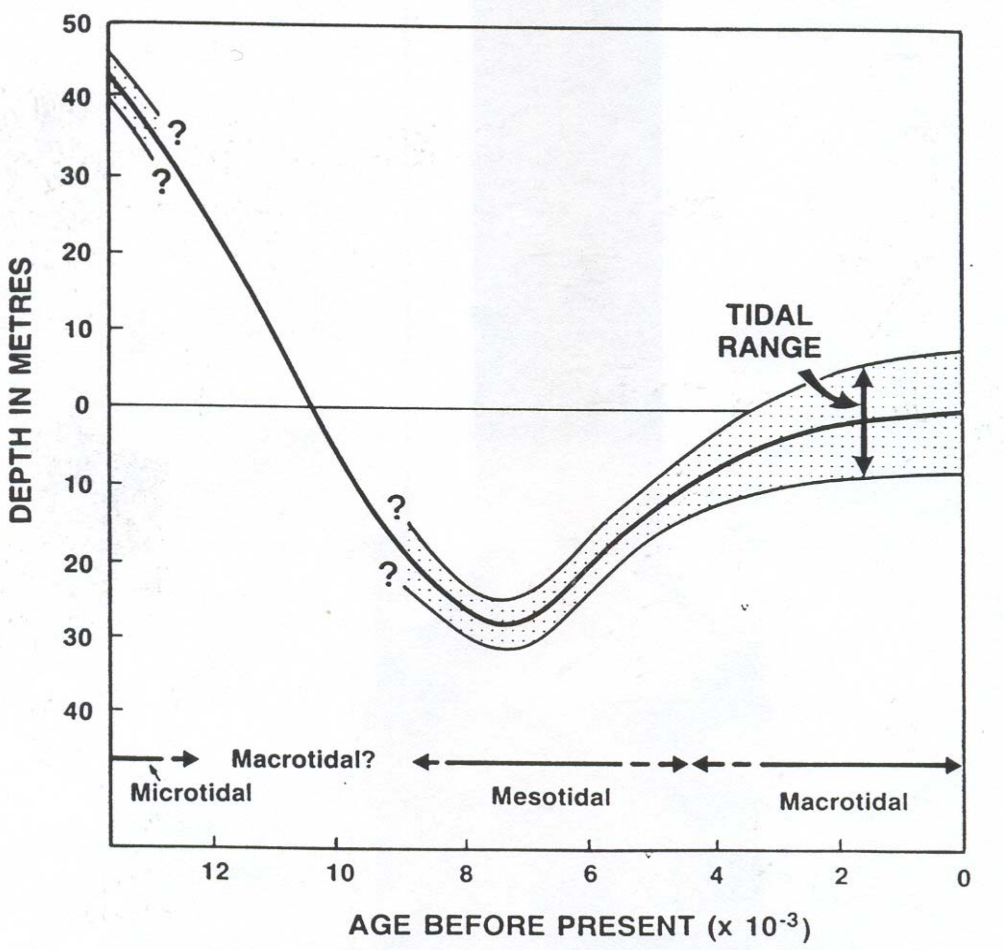

Figure 3b. *History of sea level and tidal range in the inner Bay of Fundy, based on data from Chignecto Bay (after Amos and Zaitlin, 1985). A similar pattern of sea-level and tidal range oscillations have occurred in the Minas Basin but with smaller amplitudes.*

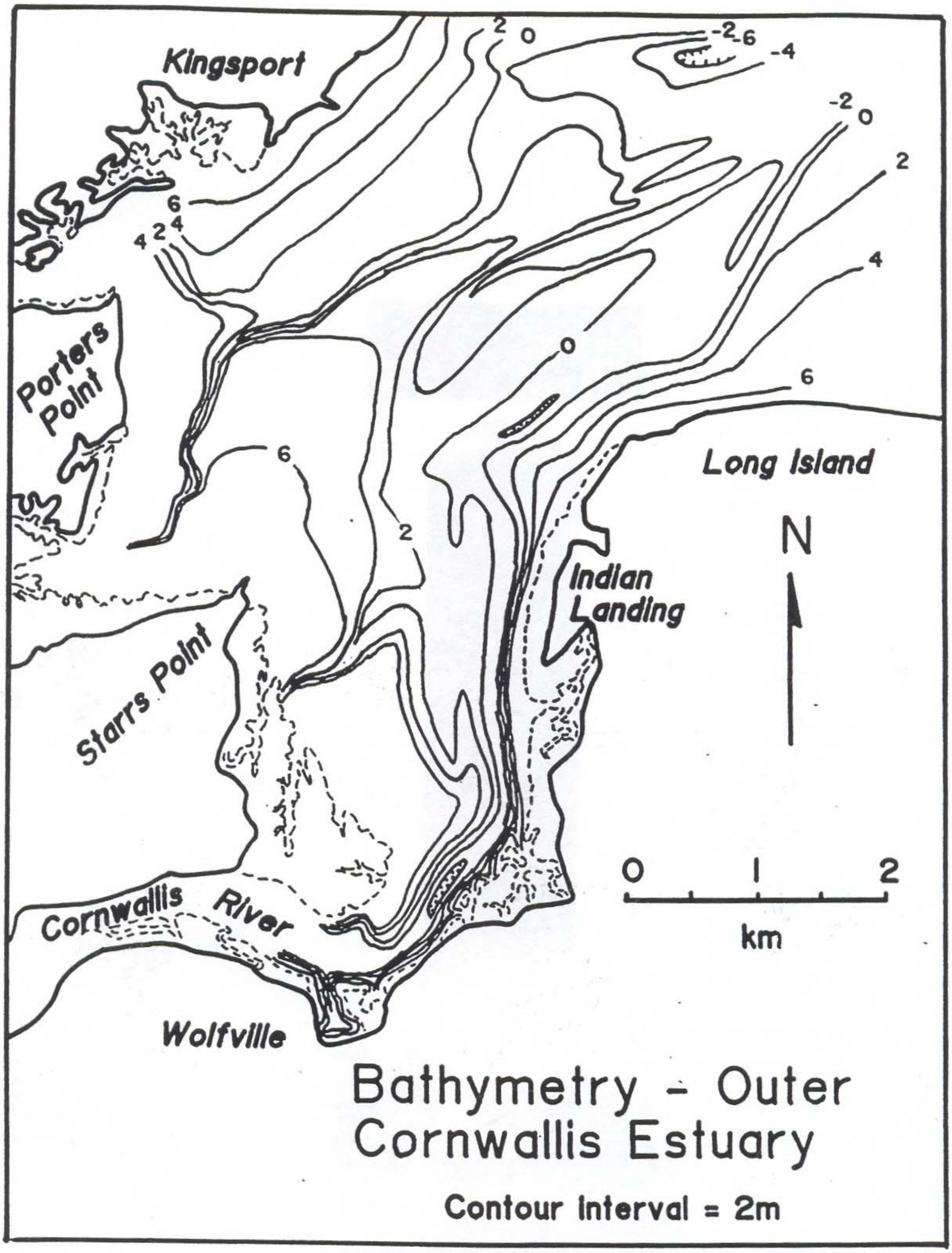

Figure 4. *Bathymetry of the outer Cornwallis River. Datum is approximately mean low water. Note the development of flood "barbs" along the west side of the Cornwallis River channel.*

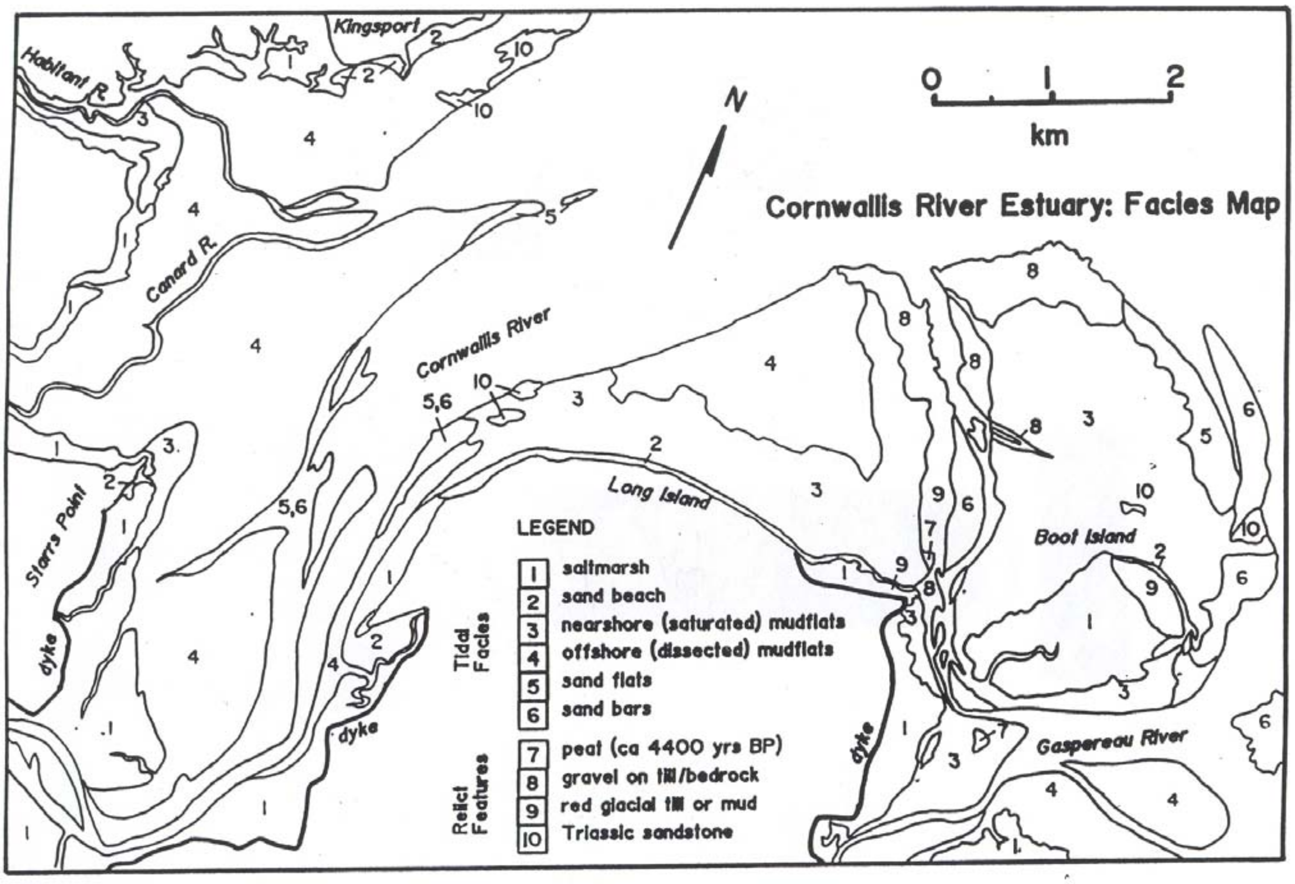

Figure 5. *Facies distribution in the outer Cornwallis River estuary. Note the sandy facies are very restricted in extent, while fringing mudflats facies are extensive.*

1.3 THE LAND OF EVANGELINE

Throughout the field trip we will be talking about the natural history of the Minas Basin Region. In particular we will be visiting Grand Pré National Park and the Grand Pré dykelands which consist of over 8000 ha of farmland below sea level (Fig. 6). The story of the Grand Pré Acadian's (greatly condensed!) is as follows. In 1680 Acadians first moved to the region from Port Royal and began reclaiming saltmarsh from the tides (see **Acadian Farming** below). As the French population of Grand Pré increased and spread over a wide district, the Acadian population exceeded that of the English at Annapolis. Gradually they were drawn into the conflict waged between the French (who controlled Louisbourg in Cape Breton Island and Quebec, and the English who controlled much of in the Bay of Fundy region (including Grand Pré) and New England.

Figure 6. *Evangeline Beach - Grand Pré area with Minas Basin and Blomidon in the background.*

The colonial power struggle between France and England was coming to a climax. Between 1755 and 1763, British authorities enforced a deportation order. This traumatic event became known as the Expulsion. This event has been immortalized by the American poet Henry Wadsworth Longfellow, when he wrote his epic poem "Evangeline".

1.4 ACADIAN FARMING

There was little that influenced the development of the Acadian way of life quite as much as their method of farming. Fortunately, among the people who settled in the Annapolis Basin area, there were some who were already familiar with methods of dyking practiced in France, and they recognized the agricultural potential of the tidal salt marshes. The new settlers moved quickly to build dykes along the outer marsh areas. Sometimes these dykes were built by driving five or six rows of logs into the ground, laying other logs one on top of the other between these rows, filling all the spaces between the logs with well packed clay and then covering everything over with sods cut from the marsh itself. Sometimes dykes were built by simply laying marsh sods over mounds of earth. The Acadians devised a system of drainage ditches combined with an ingenious one-way water gate called an aboiteau (see Fig. 11). The aboiteau was a hinged valve in the dyke which allowed fresh water to run off the marshes at low tide but which prevented salt water from flowing onto the dyked farmland as the tide rose. After letting snow and rain wash away the salt from the marshes for between two and four years the Acadians were left with fertile soil which yielded abundant crops.

1.5 AVON RIVER ESTUARY

The channel of the Avon River Estuary consists of a rock-bound. wave-cut shelf, no deeper than 10 m below lower low water (LLW). This platform is incised by a paleo-drainage system that is graded to approximately 50 m below LLW. Elongate tidal sand bars are found in this channel and have the form of ebb-tidal deltas. They are covered by active sand waves and megaripples. By far the greatest amount of sand in the Minas Basin is supplied by erosion of the Triassic sandstone cliffs that border the basin. Most of the sand that is released is either trapped in Cobequid Bay (Fig. 2) to the east, or moves westwards along the south shore of the Minas Basin and enters the Avon River estuary (Fig. 2). These flats at the outer end of the estuary are cohesive, silty mudflats that lack large-scale bedforms. They are, however, extremely productive biologically, supporting stocks of soft-shell clams and polychaetes.

The inner limit of the Avon Estuary is now near the town of Windsor as a result of a causeway. The Windsor Causeway (Figure7) was constructed between 1968 and 1970 to serve several purposes. It provides a major highway and railway crossing over the Avon Estuary that minimizes involvement of the Town of Windsor roads, and thus permits relatively high speed travel along Highway 101. The causeway removed tidal oscillations from the region upstream, protecting almost 1400 ha of previously dyked land from seasonal flooding. As a result, it yielded an additional 140 ha of farmland, and eliminated the need for maintenance of about 28 km of dykes. It also created an essentially freshwater impoundment, Pesaquid Lake, that provides recreational and aesthetic benefits to the people of the Windsor—Falmouth area, fresh water for farming and for an important ski development, and additional water storage during high runoff events.

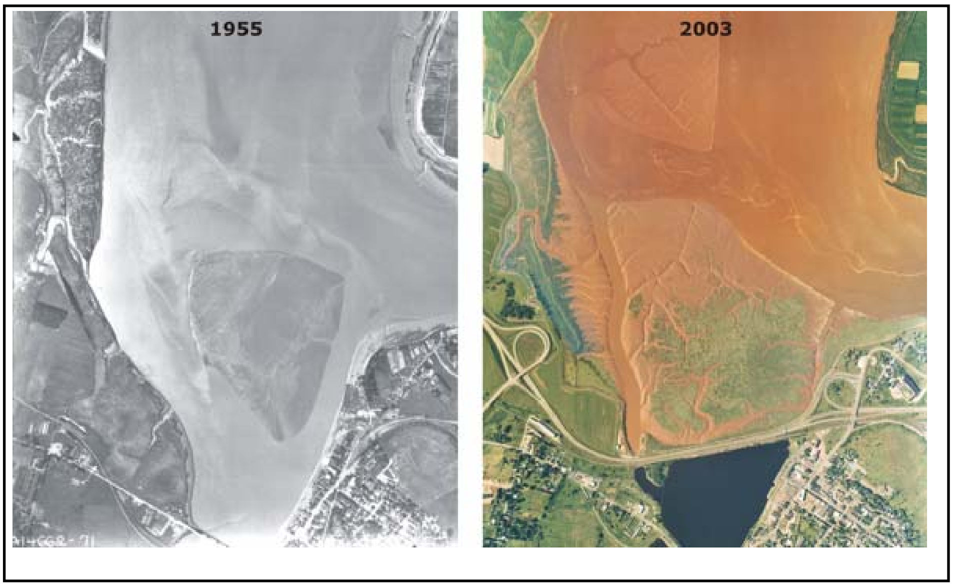

Figure 7. *a) Avon River and Town of Windsor in 1955 at high tide before causeway construction and in b) 2003, after causeway construction and significant amounts of sediment had accumulated seaward of the barrier. Note the establishment of marsh vegetation.*

1.6 FUNDY SALT MARSHES

European settlers arriving at the upper Bay of Fundy region in the 17th century would have been greeted by large expanses of saltmarsh. The shape of the basin created a sheltered embayment with abundant supplies of fine sediment, ideal for the development of large tracts of saltmarsh along the coast. Recognizing the rich agricultural potential of these marshes, early settlers quickly applied their homeland experience in reclamation and dyking to the marshes of the upper Fundy region. As mentioned previously, in order to further protect agricultural land from flooding, tidal barrages were constructed on many of the major rivers flowing into the Bay. However, the environmental implications of dyking and barrage construction were not considered. In the Upper Fundy region, the extent of saltmarshes has decreased significantly since the arrival of European settlers in the 17th century, effectively reducing marsh area available for deposition. Estuarine studies (Amos and Tee, 1989) suggest that reclamation for development and cultivation has effectively reduced marsh area available for deposition by approximately 70%. However, other, more recent studies indicate that there are also new marshes that are forming in both the Cumberland and Minas Basins. These marshes are developing seaward of existing dykelands or tidal barriers in some areas and represent an important new source of primary productivity for the estuarine food web.

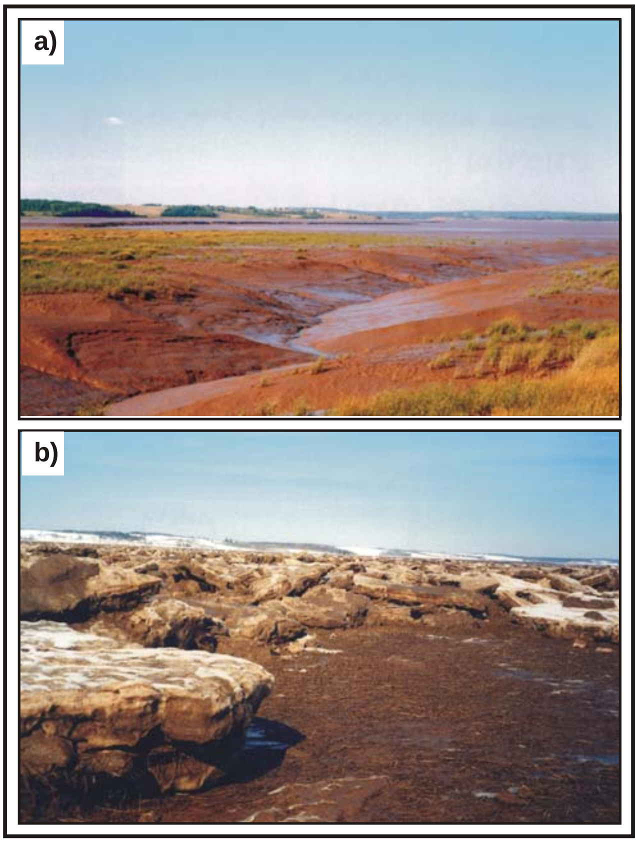

Figure 8. *a) Windsor salt marsh in late Fall, 2002; b) same location in February, 2003.*

The properties of saltmarshes are profoundly influenced by tidal elevations (Gordon *et al*., 1985). In the upper Bay of Fundy, saltmarshes are found in the upper intertidal zone near mean high water (MHW) and do not extend appreciably below the high water level of neap tides (Gordon *et al*., 1985). The primary low marsh colonizer is *Spartina alterniflora* with *Spartina patens* dominating the high marsh region. Saltmarshes increase their elevation within the tidal frame primarily as a result of deposition of sediment and below ground production. However, the relative contribution of inorganic versus organic components will vary. Foraminifera, pollen and radiocarbon data indicate that Fundy marshes undergo cycles of rapid aggradation (minerogenic) versus periods of slow aggradation (organic production and peat formation) (Shaw and Ceman, 1999). These cycles have been linked to changes in the rate of relative sea level variations; rapid aggradation occurring during relative rising sea levels, slow aggradation requiring periods of relative sea level lowering of several decimetres (Shaw *et al*., 1993; Shaw and Ceman, 1999; Allen, 2000). Currently, the mean relative sea level in the Cumberland Basin is rising at a rate of approximately 0.30-0.45 m per century (Gordon *et al.*, 1985). Palaeontological studies have indicated that saltmarshes in the Cumberland Basin have been in a cycle of rapid aggradation since AD 1600 (Shaw and Ceman, 1999) and are underlain primarily by inorganic sediments (Desplanque, 1979) and the Minas Basin would be expected to show similar trends. This aggradation or sediment accumulation is enhanced by the characteristically high suspended sediment concentrations in the Upper Fundy region, which varies seasonally, ranging from 0.05 $g \cdot l^{-1}$ at the end of the summer to 4 $g \cdot l^{-1}$ during ice break-up (Amos *et al*., 1991). Within the Fundy system, ice cakes laden with sediment have been found to be an important agent of change within salt marshes of this region, influencing the distribution of species (Fig. 8; Chmura *et al*., 1997), colonization by vegetation (van Proosdij and Townsend, 2004), mudflat erosion and sediment deposition (Gordon and Desplanque, 1983; Ollerhead *et al*., 1999; van Proosdij *et al*., 2003).

2.0 FIELD TRIP STOPS

Please note that some of these stops may be omitted due to road/access conditions!

2.1 STOP 1: WINDSOR CAUSEWAY MUDFLAT (Fig. 2; Stop 1):

Windsor causeway (Figure 2; Stop 1) is a solid-fill barrier across the Avon River estuary which was built in 1970 to support Highway 101 and a rail link between Halifax and the Annapolis Valley. The causeway blocked tidal flow into the inner Avon River estuary, thereby reducing the tidal prism by 4.2 x 106 m^3. This resulted in a significant reduction in tidal currents near the causeway, an effect that decreased exponentially with distance down estuary. Prior to construction, this part of the estuary had sandy mudflats and marshes along its margins. Ships once docked at Windsor against the crib work that now overlooks the permanently inundated river above the causeway. The region upriver of the causeway was converted from a inner estuarine environment where fines accumulated in a strongly oscillating flow, to a fluvial/lacustrine environment with flow in a seaward direction only. Seawards of the causeway, rapid deposition of muddy sediments and a dramatic shallowing resulted from the reduction in tidal current speeds. Welded to the causeway we see a region of lush salt marsh that gives way seawards to a mud flat partially colonized by *Spartina* sp. The mudflat falls away to a silt-dominated reach near the outfall of the St. Croix River and thereafter to the upper- flow-regime and rippled sand flats.

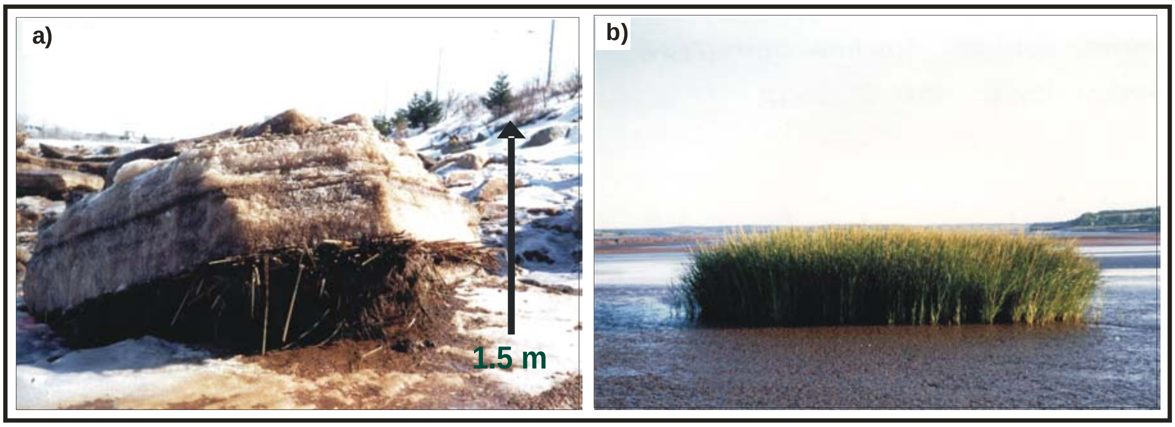

***Figure 9.** a) Ice cake containing sediment and rhizome material adjacent to the causeway in February 2002 and b) newly established ' satellite' of vegetation in July 2002 (van Proosdij and Townsend, 2004a).*

The mudflat in front of the causeway has accumulated 7m over the last 21 years. At first, accumulation was very rapid, in the order of 10 to 20 cm a month. The sediments at that time were high in water content, low in bulk density, and of very low bearing capacity therefore completely unsuitable for the successful settlement of organisms. With time, the accumulated burden, and the cyc1ical loading of tides and ice caused the sediment to consolidate. Winter freezing of the mudflat occurred due to the high water content, and large blocks of ice and sediment were commonly littered across the flats. The ice blocks, which reach 3-4 m in height, (Figure 9a), were periodically lifted on high spring tides and redistributed throughout the estuary, carrying large volumes of fines with them. In the process, the level of the mudflat was lowered by 2-3 m depending on the severity of the winter. Accumulation recurred during the subsequent spring and summer. The mudflats remained in this dynamic balance until approximately 1985, when the first *Spartina* patches appeared. The infauna were restricted to a few species only (mainly a bulbous form of the bivalve *Macoma balthica*). Since that initial colonisation (Figure 9b), probably from a few pieces of marsh ice-rafted from elsewhere in the estuary, the marsh has continued to expand through vegetative root growth (Figure 10). Current mean rates of accretion on the Windsor salt marsh/mudflat complex are 0.32 cm mth^{-1} (Daborn *et al.,* 2003; van Proosdij and Townsend, 2004b).

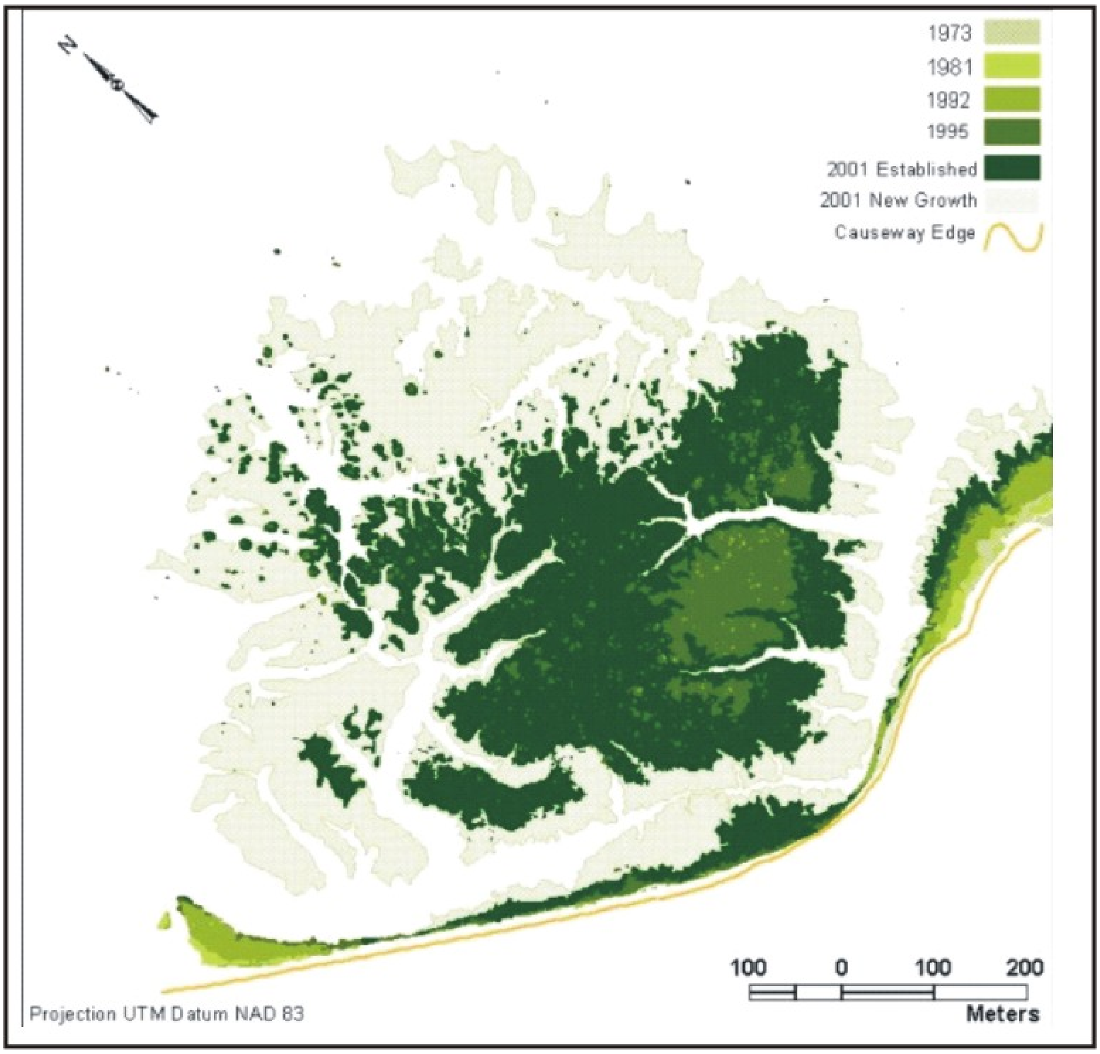

Figure 10: *GIS analysis of spatial patterns of colonization by S. alterniflora in 1973, 1981, 1992, 1995 and juvenile and mature or established S. alterniflora surveyed in 2001 (van Proosdij and Townsend, 2004a).*

Aerial photography between 1973 and 1979 shows that the mudflat has prograded approximately 5 km seawards of the causeway, to partially cover previously-existing sand bars. The remaining sand bars in the inner estuary also show evidence of long-term accretion. A comparison of bathymetric data collected in 1969 and 1976 show that 1-2 m of accretion occurred in that time interval. However, the depth of the tidal channels is highly variable, and may change by as much as 3 m within the Avon and St. Croix River on a seasonal basis. This makes it increasingly difficult to discriminate natural versus man-made effects in this case.

2.2 STOP 2 (OPTIONAL): PENNY BEACH: COASTAL EROSION – AVON RIVER ESTUARY (Fig. 2; Stop 2).

At this site (Fig. 1: Stop 2) you will be exposed to excellent examples of coastal erosion and local strategies to mitigate the process. Coastal erosion in the Minas Basin can be as much as 30 cm/year and locally, rates of >1 m/year have been noted. Most erosion occurs during the winter months as storms are frequent and often are accompanied by northwesterly winds allowing waves to build up over a maximum fetch of 30 kms. Storms that coincide with high and/or spring tides are especially damaging. As well, both chemical and mechanical (freeze-thaw) weathering can greatly accelerate coastal erosion. Local strategies for dealing with erosion are varied, most property owners use either North Mountain Basalt or South Mountain Granite as armour. Some have used (with varying degrees of success) coarse fill and brush. In many cases the placement of armour has exacerbated the problem or, worse yet, transferred the problem down the coastline.

PENNY BEACH

Penny Beach is in a transgressive phase, migrating landward over saltmarsh peat that is up to 2.5 m thick and is accumulating in the basin, landward of the present beach. This basin was formerly more extensive and the peat underlies the present sand barrier, occasionally cropping out on the beach face.

2.3 STOP 3: GRAND PRÉ NATIONAL PARK, EVANGELINE BEACH (THE GUZZLE SECTION, Fig. 2; Stop 3)

This area, which is known as Grand Pré ("large meadows") is best known as the site of a large Acadian settlement, also known as Les Mines (Fig. 2; Stop 3). This was derived from the name given to this arm of the Bay of Fundy by Champlain on the basis of his copper discovery at Cap D'Or, west of Parrsboro, in 1607 (promotion of the mineral potential of Nova Scotia is nothing new!) Acadian settlers inhabited the area from the late 1600's to 1755, when they were deported to Louisiana by the British. The ships carrying the Acadians set sail from a tidal creek a short distance to the east. Very little remains from this part of the colonial era, except for the field patterns which follow the early dyke systems. Most of the area between the railway line at the foot of the Wolfville Ridge and Long Island was formerly salt marsh that lay below the highest high tide level. It was originally reclaimed for agricultural use by the Acadians (Fig. 11).

Figure 11*. A wooden aboiteau (one way drainage valve) in a dyke near Delhaven.*

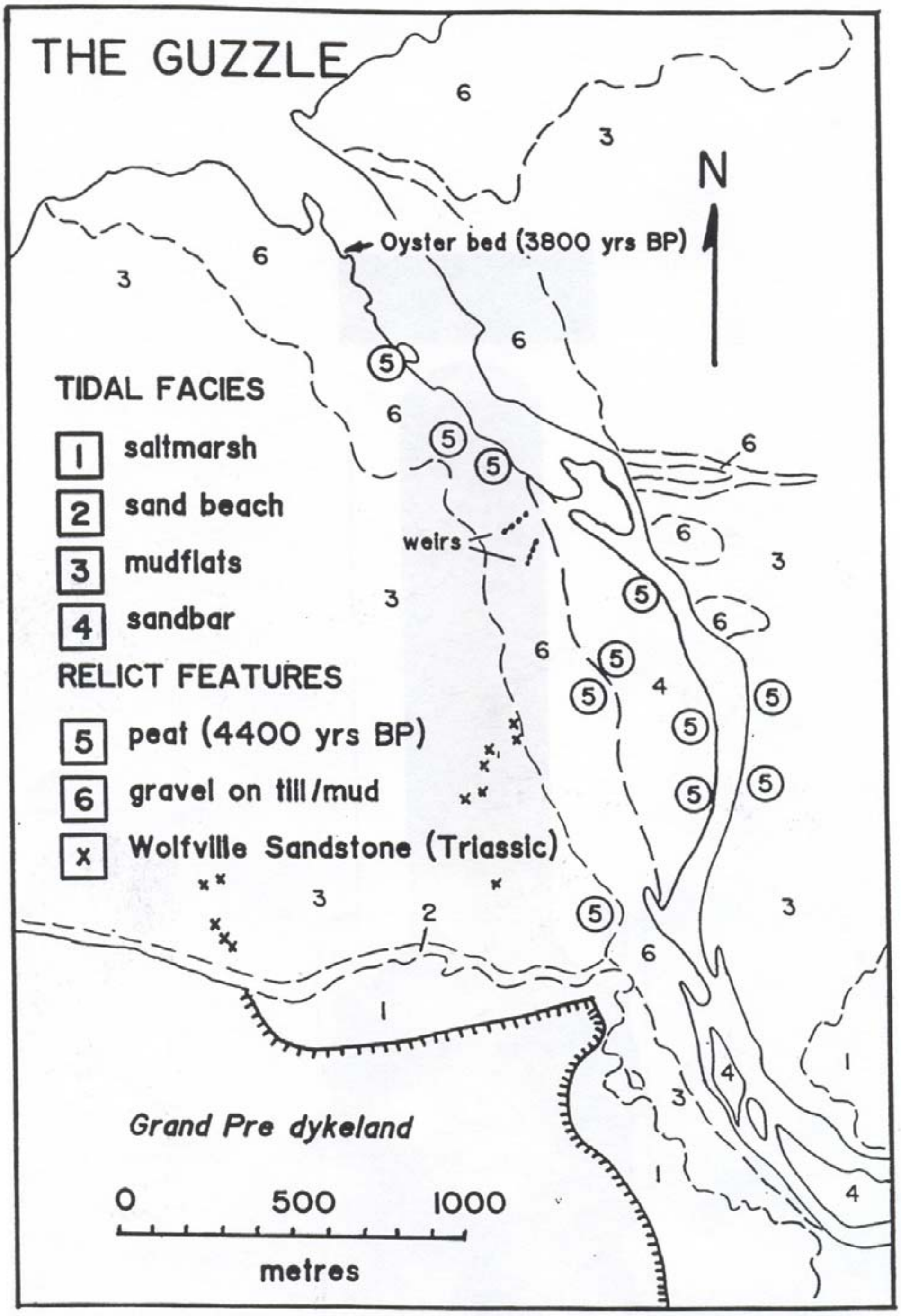

Figure 12. *Sketch map of The Guzzle area at Evangeline Beach showing the distribution of major facies and features.*

Looking northeast across tidal flats one can see Boot Island, a parcel of land separated from the mainland by a tidal gully called The Guzzle. Boot Island was joined to the mainland during the Acadian occupation and has since become isolated by the headward erosion of a tidal creek used in the deportation of the Acadians. According to a local tradition, the erosion developed from a ditch dug by a farmer. Successive maps show that the channel remained relatively narrow until the early part of this century. Between 1910 and 1940 erosion accelerated greatly but there has been relatively little erosion since then (Bleakney and Davis, 1983).

At the high water line we find a thin, modern salt marsh deposit (Fig. 5, 12) that is up to 2 m thick. Three older rooted horizons between 8 and 75 cm thick may be visible, alternating with grey silty clay layers about 20 cm thick (Ferguson, 1983). These sediments rest on a compact red boulder till, whose matrix is very poorly sorted with a mean size in the coarse silt range. Both units are being eroded by wave activity as the local transgression continues. The product of this erosion is a high tide beach made of sandy gravel and cobbles that grades seawards into a thin mudflat. Cobbles and boulders that appear to be derived from the glacial till, litter the intertidal zone.

Approximately 200 m seaward of the salt marsh, along the west bank of The Guzzle, you will encounter a series of tree stumps in growth position in a forest peat bed (Fig. 12). These mark the former presence of a pine-cedar-hemlock-oak forest (Goldthwaite, 1924) that is dated at 4470 to 3100 years B.P. (Harrison and Lyon, 1963; Bleakney and Davis, 1983). This fossil forest, which is present throughout the southern bight of the Minas Basin, provides graphic evidence of the sea-level lowstand and subsequent rise (Fig. 3b). The trees grew on exposed glacial till in areas near the present shore, and on grey and red laminated mud in more seaward areas. These muds, which also outcrop in other places in The Guzzle, may date from the period of high sea level that accompanied deglaciation 14,000 yr BP (Fig.2b). A relict salt marsh peat overlies the forest soil layer (Fig.12).

Rising sea level is indicated by the occurrence of the subtidal oysters (Fig. 12) above salt-marsh deposits and the fossil forest. Following the deposition of the oysters and the overlying mud layer, mean sea level and the high tide level have continued to rise to their present elevations. The high tide level in particular must have risen nearly 10 m as the oysters are situated approximately 13 m below the present-day high water level. By contrast, the low water level has remained approximately constant, or has fallen slightly, as the oysters are located only slightly above the spring low tide elevation.

A number of cobble-boulder ridges which trend approximately parallel to the modern shoreline are present in the lower half of the intertidal zone. Encrustation of the rocks by large barnacles indicates that these ridges are not active deposits. They are interpreted as either relict low tide, boulder barricades (Dalrymple *et al.*, 1982), or as shoreline ice-push features. Rows of wooden stakes in this area are remnants of old fishing weirs (Fig. 12)

An elongate sand bar is developed in the Guzzle (Figs. 5, 12). This sand bar is asymmetric, rising gently towards its eastern side near the main channel. The sand is well-sorted and medium grained, and small and medium dunes are developed locally. Flood flow dominates the northern part of the bar while ebb flow dominates the southern part (McDow, 1991). The sand bar crest represents an area of zero net bedload transport (i.e., ebb and flood transport are in balance). The overall morphology and distribution of large-scale bedforms suggests that sand transport is counterclockwise around the bar. Possible sources for the sand include outwash deposits such as those on Boot Island and along the lower Gaspereau River, or the sand bars at the mouth of the Avon River. Comparison of 1963 and 1987 airphotos shows that the bar has changed little, hence little or no sand is presently being supplied to it.

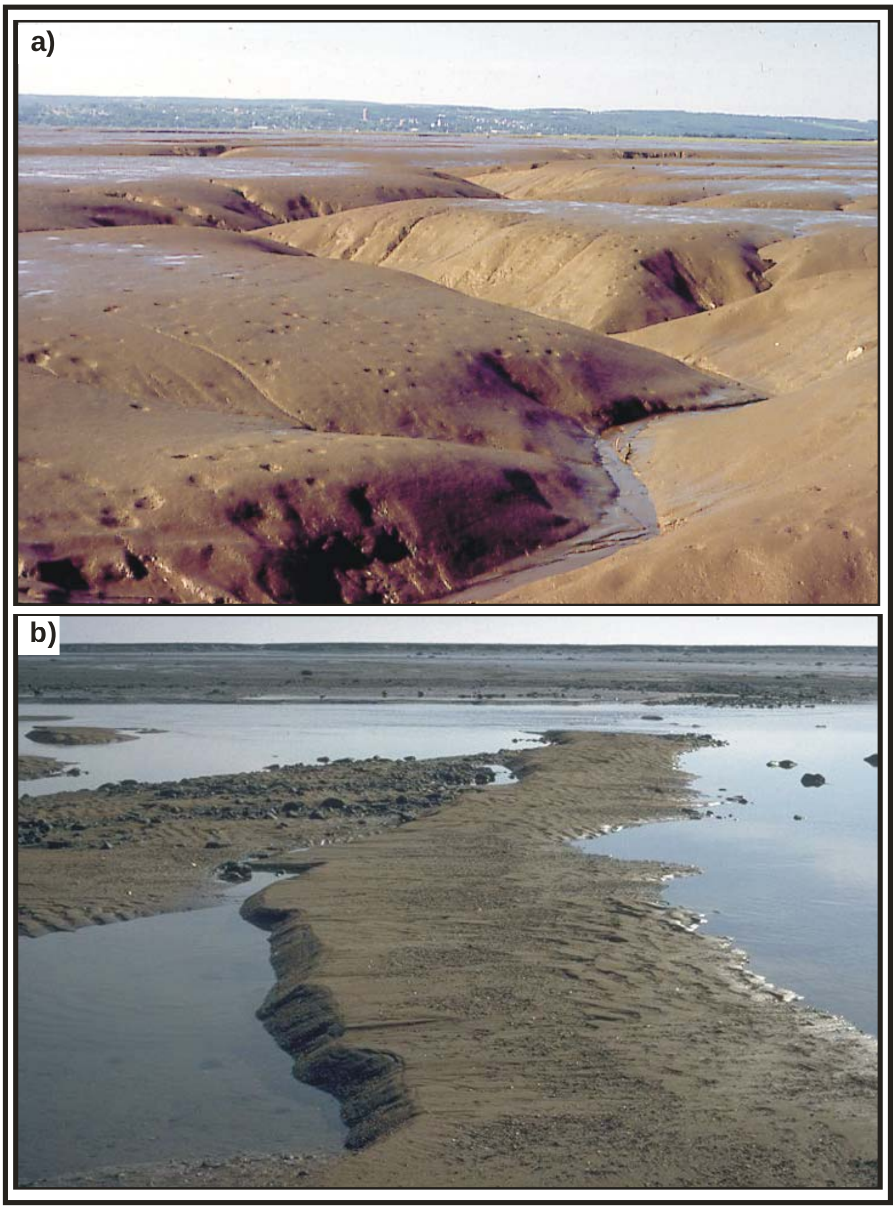

Figure 13. *a) Mudflats and channels of the inner Southern Bight (Starr's Point); b) Dune with superimposed ripples in the Southern Bight, (near Evangeline Beach)*

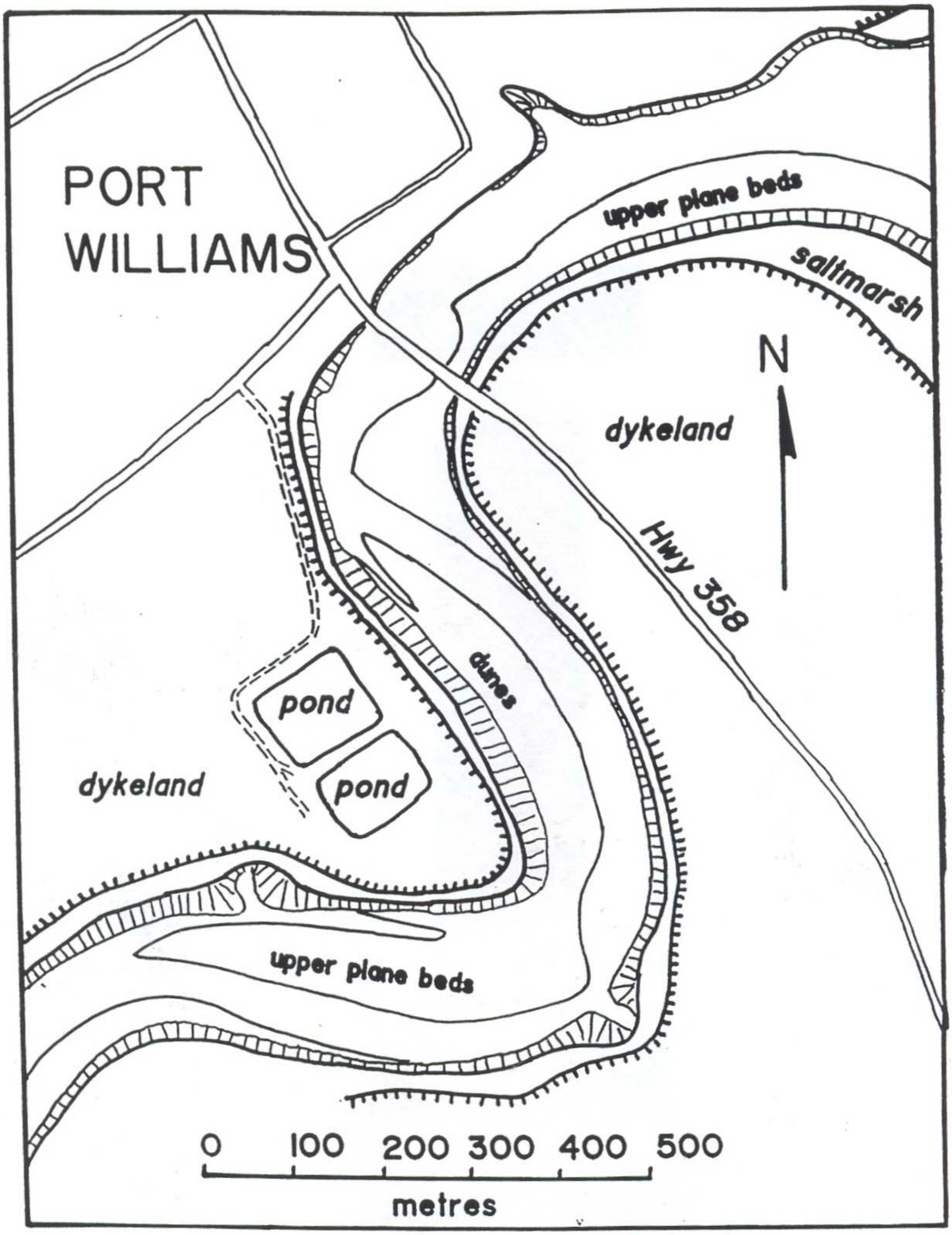

Figure 14. *Sketch map of the Cornwallis Rivers at the Port Williams bridge.*

2.4 STOP 4: PORT WILLIAMS BRIDGE : TIDAL SAND BARS (Fig. 2; Stop 4)

CAUTION: THIS IS A VERY BUSY ROAD. WATCH FOR TRAFFIC!

The Port Williams bridge locality (Fig. 2; Stop 4) lies at a transition from a relatively straight channel with bank-attached bars, and a more sinuous, meandering channel (Fig. 14). The well- developed tidal point bar that is present downstream of the bridge is the focus of this stop. Other bars located further upstream are described in subsequent paragraphs.

PORT WILLIAMS BAR (Downstream Bar)

The channel here is U-shaped, with steep banks and a relatively flat bottom. At low water, the channel width is about 42 m and depth is 0.5 m, but this varies with fluvial discharge. On a high spring tide, the water depth is 12 m and the width is about 130 m. The difference between the cross-sectional areas of the channel at spring high tide (1169 m^2) and low water (20 m^2) indicates that the fluvial discharge is less than 2% of total flow here. Suspended sediment concentration, salinity, and temperature generally increase on the flood and decrease on the ebb. Except at slack water, the flow is stratified, with the stratification being strongest during the first two hours of flood tide. The average salinity observed at the Port Williams Bridge was 21‰, and the maximum suspended sediment concentration was 442 mg/l.

Muddy suspension deposits accumulate on the bank at high water, but undercutting of the oversteepened banks results in slumping. Here the banks are stabilized artificially by rip-rap, to prevent erosion of the dykes. As observed elsewhere in the Cornwallis estuary, there is essentially no long-term net accretion or erosion apparent at the Port Williams bar. The lower portion of the point bar (Fig. 15) is composed predominantly of sandy bedload deposits, although organic debris is noticeably more abundant at the upriver end. Ebb-dominant bedforms and structures are preserved on the upriver end of the bar, whereas flood-dominant structures are present on the downriver end because that area is sheltered from the full force of the ebb currents.

Figure 15. *The Port Williams Bar downstream of the Port Williams bridge.*

The largest bedforms occur on the lower part of the bar, near the centre of the channel, and consist of medium dunes of two types. Along the margin of the low-tide channel at the upriver end of the bar, sinuous-crested dunes with avalanche-type foresets and current-lineated topsets may form a point projecting into the channel. These are composed of very coarse sand and granules, and have wavelengths of 2-6 m and heights of about 0.5 m. A box core from the sediments below the dunes in this area revealed preserved, ebb-dominant, planar cross beds in sets only 4-6 cm thick. No muddy drapes were present. Higher on the bar in the same area, dunes with rounded, relatively straight crests may be present in the medium-grained, moderately sorted sand that characterizes this topographically higher area. These have wavelengths of 1-4 m and heights of about 0.5 m. Clay drapes that are deposited from suspension during falling water are common in the scour pits, and late ebb-stage, linguoid and parallel-crested ripples often occur on their stoss side and crest. Two box cores from between these dunes show that the preserved cross beds are flood-oriented and occur in sets 2-16 cm thick. Both planar and trough cross bedding is present. Mud drapes and silty mud balls up to 6 cm in diameter that were eroded from the channel bank are preserved. Significant changes in the structures may occur between spring and neap tides, but these have not been documented thoroughly.

Still higher on the bar, the dunes pass shoreward, first into linguoid ripples and then into straight-crested ripples. The sands on this part of the bar are very fine-grained, and fluid mud drapes are present in low areas at low water. A box core from an area of straight-crested ripples on the highest part of the bar showed a set of ebb-oriented trough cross-bedding 8 cm thick that passes up into topset laminae that dip gently both down- and upriver. A box core from a linguoid rippled area at the upriver end of the bar showed ebb-dominant climbing ripples in cosets up to 6 cm thick. Clay drapes and organic debris were abundant. In the next bar downriver, dunes also pass laterally into linguoid and straight- crested ripples higher on the bar (Dickinson, 1991). The cross- bedding here is ebb-dominant, but alternates with parallel planar lamination that may have formed during upper-flow-regime conditions during flood tides.

UPRIVER BARS

The main accumulation of coarse-grained sediment in the inner estuary is found in the short reach immediately upriver from the Port Williams Bridge (Figs. 14, 16, 17). This bar, which is composed of medium to very coarse-grained sand, is attached to the north bank at its higher, upriver end and separated from the north bank by a flood barb at its downriver end. This bar is best reached by climbing down the bank from the north dyke at its upriver high point. The medium dunes which cover this bar have wavelengths of about 4 m and heights of up to 40 cm. The concentration of coarse sand in this reach suggests that ebb and flood flow may be in balance here (i.e., ebb flow predominates upstream and flood flow predominates downstream from this reach). A box core from the upriver end of this bar showed alternating ebb and flood sets 3-19 cm thick. In contrast with the dunes on the Port Williams bar, silty mud drapes were preserved here.

Figure 16. *The Upstream bar at the Port Williams Bridge*

In the next reach upriver from this area of coarse sediment, a large bar of moderately well sorted, fine sand with an ebb barb is attached to the north bank of the river. Late ebb-stage ripples are developed on its surface. A box core from this bar showed mainly horizontal plane lamination, interrupted by a ripple laminated coset 10 cm thick. Ripple foresets 0.5-2 cm high dip alternately up-and downriver, but an ebb-orientation predominates. The prevalence of plane lamination indicates that upper plane bed conditions are common here. Bank-attached bars situated downriver of Port Williams also contain moderately well-sorted fine-grained sand and upper-flow-regime parallel lamination, but are flood dominated.

Figure 17. *Tidal meanders upstream of the Port Williams Bridge*

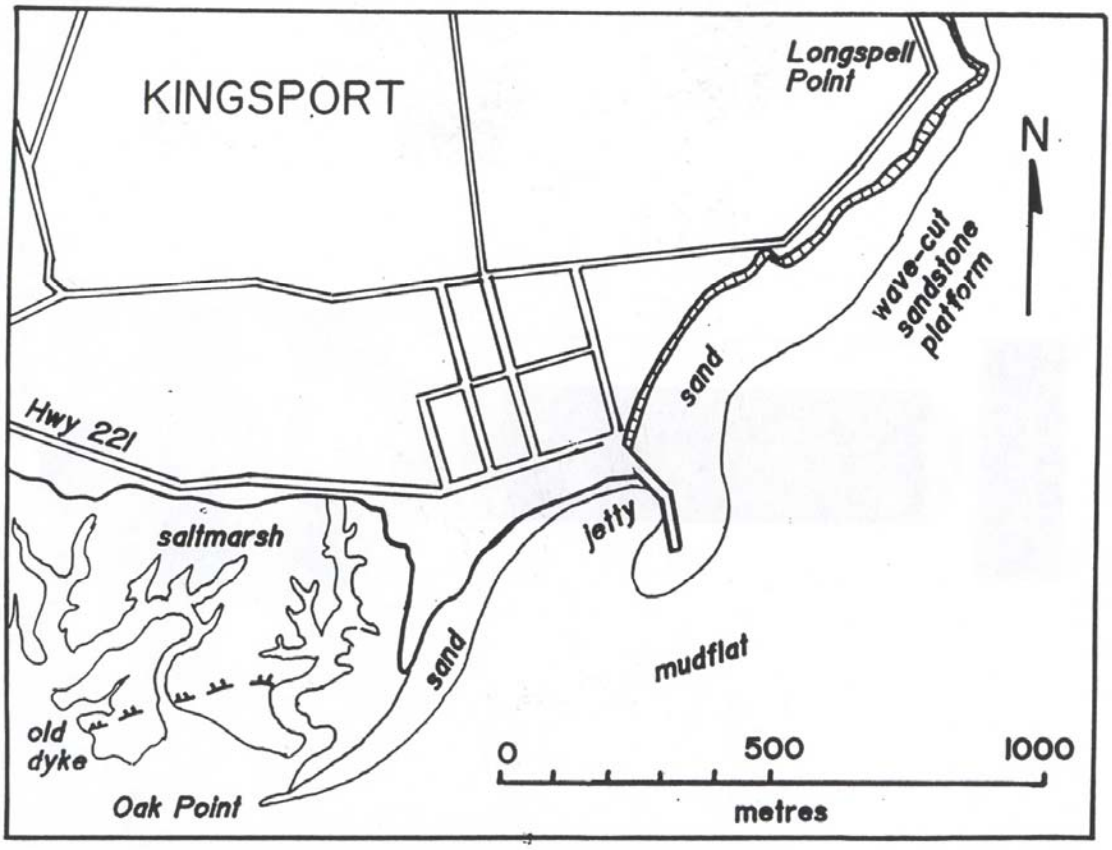

Figure 18*. Sketch map of Kingsport at the seaward limit of the Cornwallis estuary. Saltmarsh and Mudflats of the outer estuary give way between Oak Point and Kingsport wharf to a sediment-starved, wave-cut platform with a sand beach at the high tide level. This change reflects a seaward increase in the influence of wave action, and a change from tide dominated to mixed energy sedimentation*

2.5 STOP 5: KINGSPORT WHARF (Fig. 2; Stop 5)

To the north you can see the eroding Triassic siltstone cliffs that provide the majority of sediment to the Cornwallis River and Avon River estuaries (Fig.18) The cliffs here are capped by glacial till and glacio-fluvial outwash. The influence of both waves and tidal currents is evident in the sequence of intertidal sediments. The high water mark is occupied by a wave-formed sandy beach which consists of material winnowed from the glacial sediments. Seawards, the sand gives way to either a bare, rock-cut platform (diagnostic of limited sediment supply), or a veneer of mudflat and occasional salt marsh. The mudflat grades seawards into sandy silt and thereafter into exposed bedrock. Mobile sand is found only in the base of tidal channels below the low water level. The bedrock exposed at low water shows a distinct bevel that is likely the result of wave erosion. The intertidal sediments in this region have a low preservation potential. The sand is slowly moved southwards around the government wharf and over the transgressed Acadian salt marsh, producing Oak Point (Fig. 18).

To the south of the government wharf, a much thicker sedimentary succession is developed because of the sheltering provided by the wharf. A wave-formed beach is still present at the high water level, but this gives way outward to a well developed salt marsh and mudflat. The level of the salt marsh is artificially low due to the sheltering effects of the wharf.

2.6 STOP 6: DELHAVEN WHARF (Fig. 2; Stop 6)

A short stop at the Delhaven Wharf (Fig. 19) may provide us with a good opportunity for a photo depicting the full tidal range in the Minas Basin. Boats at this and other localities in the area have to use unique mooring techniques to compensate for the extreme tidal range (Fig. 19). This is a good example of one of the small fishing communities on the Minas Basin, the boats that dock here are inshore craft that exploit a wide variety of species (most commonly lobster) over the course of the year.

Figure 19. *Fishing Boats at low tide at the Delhaven Wharf*

2.7 STOP 7: THE LOOKOFF (Figure 2; Stop 7)

The Lookoff (Fig. 20) affords a splendid view of Windsor Bay and the Cornwallis River-Avon River estuarine system; to the south, and of the eastern end of Annapolis Valley in which these estuaries are partially situated. The Annapolis Valley is located on the south limb of the plunging syncline of Triassic basalt that forms Cape Split, Cape Blomidon, and the North Mountain. It is this feature that separates the wave dominated, high-energy outer Bay of Fundy from Minas Basin. On the seaward side, waves reaching 4 m in significant height have created an intertidal rock platform devoid of sediments. These waves in association with strong tidal currents are reworking the glacio-marine sequence which underlies much of the main Bay of Fundy (Fader *et al.*, 1977). The sand fraction has been moulded into large sand waves and mega-ripples that are migrating northeastwards into Scott's Bay which occupies the centre of the syncline. The fines are swept through Minas Passage and into the Minas Basin where they accumulate in the inner reaches of the estuaries and embayments along the coastline.

The tidal amplification, and the associated increase in tidal current speeds, lead to a migration of the depocentre from the centre of the basin to the margins, with reworking of material in deeper water. Present-day bottom sediments of Windsor Bay show a progressive decrease in grain size landward from cobbles and boulders of the subtidal zone off Cape Blomidon, through gravelly sand to sand off Kingsport (Stop 5), and to silt off Evangeline Beach (Stop 3). Clay predominates still further up the Cornwallis River, beneath the turbidity maximum.

Figure 20. *A view from the Lookoff*

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Figure 21: *Dykeland, mudflat and developing salt marsh system near Grand Pré*

Pre-conference Field Trips

A1 Contamination in the South Mountain Batholith and Port Mouton Pluton, southern Nova Scotia
D. Barrie Clarke and Saskia Erdmann

A2 Salt tectonics and sedimentation in western Cape Breton Island, Nova Scotia
Ian Davison and Chris Jauer

A3 Glaciation and landscapes of the Halifax region, Nova Scotia
Ralph Stea and John Gosse

A4 Structural geology and vein arrays of lode gold deposits, Meguma terrane, Nova Scotia
Rick Horne

A5 Facies heterogeneity in lacustrine basins: the transtensional Moncton Basin (Mississippian) and extensional Fundy Basin (Triassic-Jurassic), New Brunswick and Nova Scotia
David Keighley and David E. Brown

A6 Geological setting of intrusion-related gold mineralization in southwestern New Brunswick
Kathleen Thorne, Malcolm McLeod, Les Fyffe, and David Lentz

A7 The Triassic-Jurassic faunal and floral transition in the Fundy Basin, Nova Scotia
Paul Olsen, Jessica Whiteside, and Tim Fedak

Post-conference Field Trips

B1 Accretion of peri-Gondwanan terranes, northern mainland Nova Scotia and southern New Brunswick
Sandra Barr, Susan Johnson, Brendan Murphy, Georgia Pe-Piper, David Piper, and Chris White

B2 The Joggins Cliffs of Nova Scotia: Lyell & Co's "Coal Age Galapagos"
J.H. Calder, M.R. Gibling, and M.C. Rygel

B3 Geology and volcanology of the Jurassic North Mountain Basalt, southern Nova Scotia
Dan Kontak, Jarda Dostal, and John Greenough

B4 Stratigraphic setting of base-metal deposits in the Bathurst Mining Camp, New Brunswick
Steve McCutcheon, Jim Walker, Pierre Bernard, David Lentz, Warna Downey, and Sean McClenaghan

B5 Geology and environmental geochemistry of lode gold deposits in Nova Scotia
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B6 The macrotidal environment of the Minas Basin, Nova Scotia: sedimentology, morphology, and human impact
Ian Spooner, Andrew MacRae, and Danika van Proosdij

B7 Transpression and transtension along a continental transform fault: Minas Fault Zone, Nova Scotia
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B8 New Brunswick Appalachian transect: Bedrock and Quaternary geology of the Mount Carleton – Restigouche River area
Reginald A. Wilson, Michael A. Parkhill, and Jeffrey I. Carroll

B9 Gold metallogeny in the Newfoundland Appalachians
Andrew Kerr, Richard J. Wardle, Sean J. O'Brien, David W. Evans, and Gerald C. Squires