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# STRATIGRAPHY AND SEDIMENTOLOGY OF THE CONNECTING POINT GROUP AND RELATED ROCKS, BONAVISTA BAY, NEWFOUNDLAND: AN EXAMPLE OF A LATE PRECAMBRIAN AVALONIAN BASIN

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## ABSTRACT

*The Connecting Point Group in the Bonavista Bay area is composed of a thick pile of uppermost Precambrian epiclastic, marine turbiditic sandstone, siltstone, shale and silicified sediment. The succession lies conformably above the mainly volcanic Love Cove Group and unconformably beneath the volcanic and siliciclastic Musgravetown Group. Black shale and interbedded pyroclastic rocks of the upper part of the Love Cove Group underlie the turbidites, but are also intercalated in the lower 500 m of the Connecting Point Group. To date, a total of six lithostratigraphic units and ten distinctive lithofacies, which comprise a 3.5-km-thick sedimentary pile, have been recognized within the Connecting Point Group in the study area. Sediments in this succession include lithofacies deposited in basinal and slope settings, prograding fan lobes and channel–levee complexes of submarine fans.*

*Predominance of $T_a$ turbidites and poor development of coarsening- and fining-upward sequences in the lower 800 m of the group suggest that the sediments were deposited on a low-efficiency submarine fan as part of a thick volcaniclastic apron that lay adjacent to a volcanic centre. The well-developed channel–levee complex that comprises the next 1000 m of the succession suggests a change to a more efficient fan with time. Both lateral shifting and avulsion of channels occurred.*

*A thick shale transition containing thin siltstones and cherts, small- to large-scale slumps, and a regionally significant mixtite deposit comprising a mixture of sedimentary olistoliths and volcanic clasts, overlie the lower sequence. An upper sequence, above the mixtite, of silicified, classical turbidites are arranged in stacks of coarsening- and thickening-upward sequences, suggesting the existence of a series of well-developed, overlapping, prograding submarine fan lobes. The separation of the rocks into two distinct sequences is coincident with: 1) the introduction of mixtite into the basin, 2) the intrusion of mafic dykes and plutons, and 3) the influx of coarse volcanic detritus indicative of uplift of a volcanic source; these events suggest an episode of basin growth.*

*The lithostratigraphy and characteristics of the upper part of the Love Cove Group and the overlying Connecting Point Group resemble Cenozoic models of sedimentation in volcanic-arc basins. The linear Precambrian volcanic and sedimentary belts in the Avalon Zone may reflect an ancient arc–basin geometry affected only slightly by subsequent deformation.*

## INTRODUCTION

This report presents the preliminary results of detailed stratigraphic and sedimentological studies of the Connecting Point Group (Hayes, 1948) recently undertaken by the authors. In 1986 and 1987, our work focused mainly on the lower portion of the group, which is best exposed on the numerous islands west and northwest of the community of Burnside in southwest Bonavista Bay. Detailed sections were logged through the group in two southwest–northeast transects along the shores of 1) Long Reach and Pretty islands and 2) Hail and Coal islands. The study area was expanded in 1987 to include higher stratigraphic levels of the group exposed in the vicinity of Salvage and Eastport.

The aims of this study are four-fold. Through detailed sedimentological and stratigraphic analyses, coupled with regional systematic mapping, we hope to:

1) establish a regional stratigraphy for the Connecting Point Group,
2) establish the group's paleogeographic setting,
3) compare and contrast the evolution of late Precambrian basins in southeastern Newfoundland, and in doing so,
4) use depositional history of these basins to provide insight into the tectonic setting of the Avalon Zone.

The Connecting Point Group is an extensive succession of late Precambrian, marine, siliciclastic sedimentary rocks that forms a southward-narrowing belt underlying more than 3000 km$^2$ between Offer Gooseberry Island in Bonavista Bay and Long Island in Placentia Bay (Figure 1). The group occupies a stratigraphic position conformably above the mainly volcanic Love Cove Group and unconformably beneath the late Precambrian to ?Early Cambrian sedimentary and volcanic Musgravetown Group.

This project is a contribution to the Canada–Newfoundland Mineral Development Agreement, 1984–1989

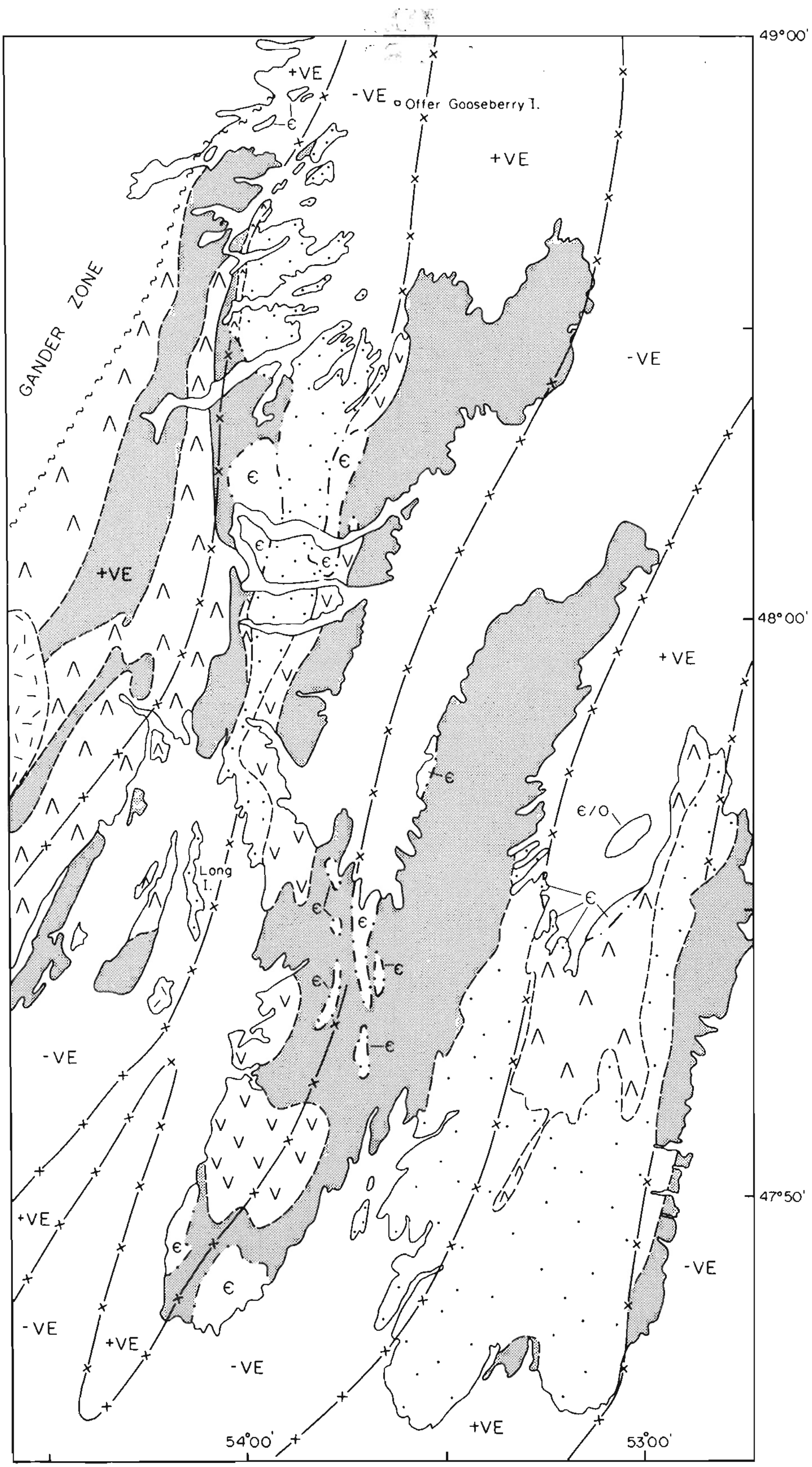


**Figure 1.** *Regional distribution of volcanic and sedimentary rocks of the Avalon Zone. The aeromagnetic belts of Haworth and Lefort (1979) are also shown (see legend).*

**LEGEND** (Figure 1)

- *Intrusive rocks*
- *Cambrian–Ordovician sedimentary rocks*
- V *Late Hadrynian sedimentary and volcanic rocks; includes Musgravetown Group*
- Connecting Point Group–Conception Group: *mainly sedimentary rocks*
- Λ Love Cove Group–Harbour Main Group: *mainly volcanic rocks*

**KEY**

—·—·— *Unconformity*

—x— *Boundary of magnetic belts of Haworth and Lefort (1979)*
*+ve positive magnetic belt*
*–ve negative magnetic belt*

~~~~ *Fault*

The Connecting Point Group in the map area (Figure 2) is a succession of epiclastic, turbiditic sandstone, siltstone and shale containing subordinate amounts of chert, tuff and mixtite. The group is at least 3500 m thick. A total of 2400 m of section has been studied, primarily in the lower part of the group. The upper 780 m of the underlying Love Cove Group contains black shale, fine- to coarse-grained vitric, crystal and lithic tuff and agglomerate, and minor interbeds of thin turbiditic sandstone and volcanic breccia.

The sections studied on the islands west of Burnside (Figure 2, Figure 3) are part of an eastward-facing succession on the vertical to inverted western limb of the Willis Reach syncline (O'Brien and Knight, *this volume).* High-strain effects, combined with secondary silicification and the thermal effects of widespread dyking, hamper the definition of sedimentary structures in these sections. The sections near Eastport (Figure 2, Figure 4) lie mainly within the gently to moderately dipping eastern limb of an anticline. Sedimentary rocks of the Connecting Point Group in this limb, extensively silicified in places, are not highly strained.

Sections were measured using a metre stick. Where covered intervals were encountered, their thickness was calculated using measured horizontal distances multiplied by the sine of the angle of dip. Grain size of sandstones was visually estimated.

## STRATIGRAPHY

In the study area, the Connecting Point Group is divisible into six lithostratigraphic units (O'Brien, 1987; O'Brien and Knight, *this volume).* The first five of these units have been mapped extensively on the western limb of the Willis Reach syncline; the younger units (C-3 to C-6) were mapped east of the synclinal core, where the older units are missing (Figure 2).

The six lithostratigraphic units, with brief summaries of their characteristic lithology, are listed below, in order of decreasing age. The various lithofacies are discussed in detail below (see LITHOFACIES).

### UNIT C-1

*Thin-bedded, green-grey and buff, tuffaceous sandstone and siltstone, black shale and rare fine grained pyroclastic rocks, and coarse grained epiclastic breccia.* Although this unit is predominated by thin-bedded, tuffaceous siltstone and sandstone (lithofacies F and D), thicker massive sandstone (lithofacies G-1) is intercalated sporadically. Minor lithofacies in this unit are facies A-1, B and H. Sequences that show bed thickness and grain-size trends are not obvious. The unit is approximately 400 m thick.

### UNIT C-2

*Thick- to thin-bedded, commonly amalgamated, graded sandstone containing interbeds of thin-bedded green-grey sandstone and shale.* This unit, predominated by lithofacies F and G, contains variably developed thickening- and coarsening-upward sequences involving shale (lithofacies A-1), thin- to thick-bedded, graded sandstone (lithofacies F and G-1) and rare pebbly sandstone (lithofacies G-1). The unit is pproximately 370 m thick.

### UNIT C-3

*Green-grey to buff, thinly bedded, very fine grained sandstone, siltstone and shale enclosing large lenticular units*
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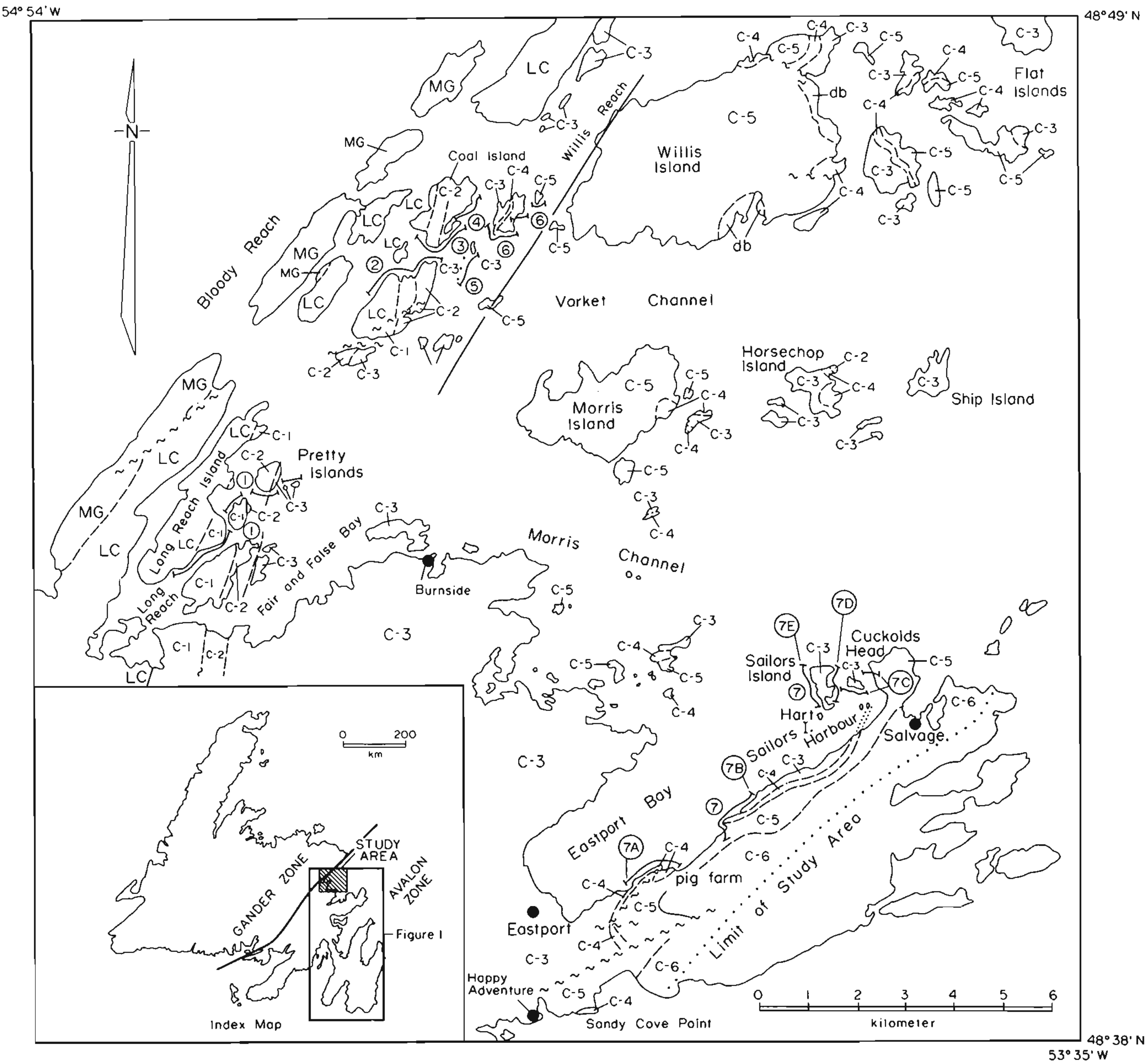


**Figure 2.** *Geologic map showing lithostratigraphy of the Connecting Point Group in the Eastport–Salvage area of Bonavista Bay. Numbered sections illustrated in Figures 3 and 4 are also shown.*

*of massive and pebbly sandstone (lithofacies E and G).* Black shale (lithofacies A-1 and A-2) is locally intercalated in the unit. A minimum of 1000 m of this unit is exposed in the study area.

## UNIT C-4

*Mixtite.* This unit varies from 11 m to 17 m in thickness, and is a widely distributed marker in the map area. It contains sedimentary, volcanic and minor plutonic clasts that are set in a muddy matrix. Locally, the mixtite (lithofacies I) appears to pass laterally into shale and thin-bedded siltstone and sandstone (lithofacies A-3) deformed by medium- to large-scale slump folds.

## UNIT C-5

*Shale containing thin-bedded sandstone and siltstone, colour-banded shale and siltstone, thick sandstone, slump beds and chert.* Small- to large-scale slump folds, slump breccia, slides and slump scars are present within shale and siltstone (lithofacies A-3) of the unit, especially in the Eastport–Salvage area. Colour-banded shale and siltstone (lithofacies C), unaffected by synsedimentary deformation, forms an important part of this unit in the vicinity of Willis Reach. Distinctive, thick units of sandstone (lithofacies G and H) overlie the mixtite on Willis and Morris islands in the northeastern part of the area. These units display well-developed, internal, planar, thin stratification (see Plate 4 of

**LEGEND** (Figure 2)

**UPPER PRECAMBRIAN**

| | |
|---|---|
| MG | *Undivided Musgravetown Group* |
| | **Connecting Point Group (Units C-1 to C-6)** |
| C-6 | *Black shale, thin-bedded argillite, silicified thin- to medium-bedded turbidite sandstone.* |
| C-5 | *Shale, thin-bedded sandstone and siltstone, and thick units of sandstone; planar stratified and slumped sandstone.* |
| C-4 | *Mixtite containing pebble- and boulder-sized clasts of sedimentary rocks together with mafic and felsic volcanic and plutonic detritus.* |
| C-3 | *Green-grey to buff, thin-bedded sandstone, siltstone and shale containing units of massive pebbly sandstone and black shale.* |
| C-2 | *Thick-bedded, thin-bedded and amalgamated turbidite sandstone containing minor thin-bedded, green-grey sandstone and shale.* |
| C-1 | *Thin-bedded green-grey and buff tuffaceous sandstone and siltstone; black shale; rare pyroclastic rocks.* |
| LC | *Undivided Love Cove Group* |

**SYMBOLS**

~~~ *Fault*

— — — *Stratigraphic contact*

⑤ *Location and number of logged section*

O'Brien and Knight, *this volume)* that is, in many places, convoluted. In general, thin sandstone and siltstone units are unsystematically distributed throughout the shales. However, some coarsening- and thickening-upward sequences involving shale (lithofacies A-2) and sandstone (lithofacies F-2 and F-1) occur near the top of the unit. The unit is at least 500 m thick.

### UNIT C-6

*Thin- to thick-bedded sandstone and shale.* These sandstones display characteristic features of turbidites (lithofacies F and locally G-1), and are arranged in well-developed, coarsening- and thickening-upward sequences with thicknesses as great as 70 m. The top of the unit has not been mapped but the minimum thickness is 900 m.

The Connecting Point Group conformably overlies the Love Cove Group. On Hail Island, the conformable contact is placed where a continuous succession of well-bedded, fine grained, epiclastic sedimentary rocks rest upon coarse pyroclastic rocks and interbedded shales of the Love Cove Group (St. Brendan's map area (2C/13), grid reference 2946, 540535). The two groups are compositionally similiar, and contain common lithofacies (see Table 1). Shales and pyroclastic rocks predominate near the top of the Love Cove Group and form minor units in the basal unit of the Connecting Point Group. Similarly, units of thin-bedded shale and tuffaceous sandstone are in many places interdigitated with volcanic rocks in the upper unit of the Love Cove Group. These observations indicate that the contact between these groups is transitional.

## LITHOFACIES

Ten lithofacies are recognized in the Connecting Point Group. Lithofacies A, B, D and F also occur in varying proportions in the underlying Love Cove Group. Lithofacies is here used in accordance with definition b in the Glossary of Geology (Bates and Jackson, 1987, page 383) as 'a term used by Moore (1949) to signify any particular kind of sedimentary rock or distinguishable rock record formed under common environmental conditions of deposition, without regard to age or geological setting or without reference to designated stratigraphic units, and represented by the sum total of the lithologic characteristics of the rock.'

### Lithofacies A: Shale

*Description.* Shales found in the Connecting Point and Love Cove groups are divisible into three subfacies. The first (subfacies A-1) consists of thick sequences of generally monotonous black shale containing fine siliciclastic laminations, thin grey chert beds and minor fine grained schistose tuff. The shale is sulphurous, pyritic and commonly rusty. It is found mostly in Unit C-1 of the Connecting Point Group and in the Love Cove Group. Subfacies A-2 consists of black to grey shale that contains lenses and thin beds of laminated siltstone, and/or crosslaminated and laminated
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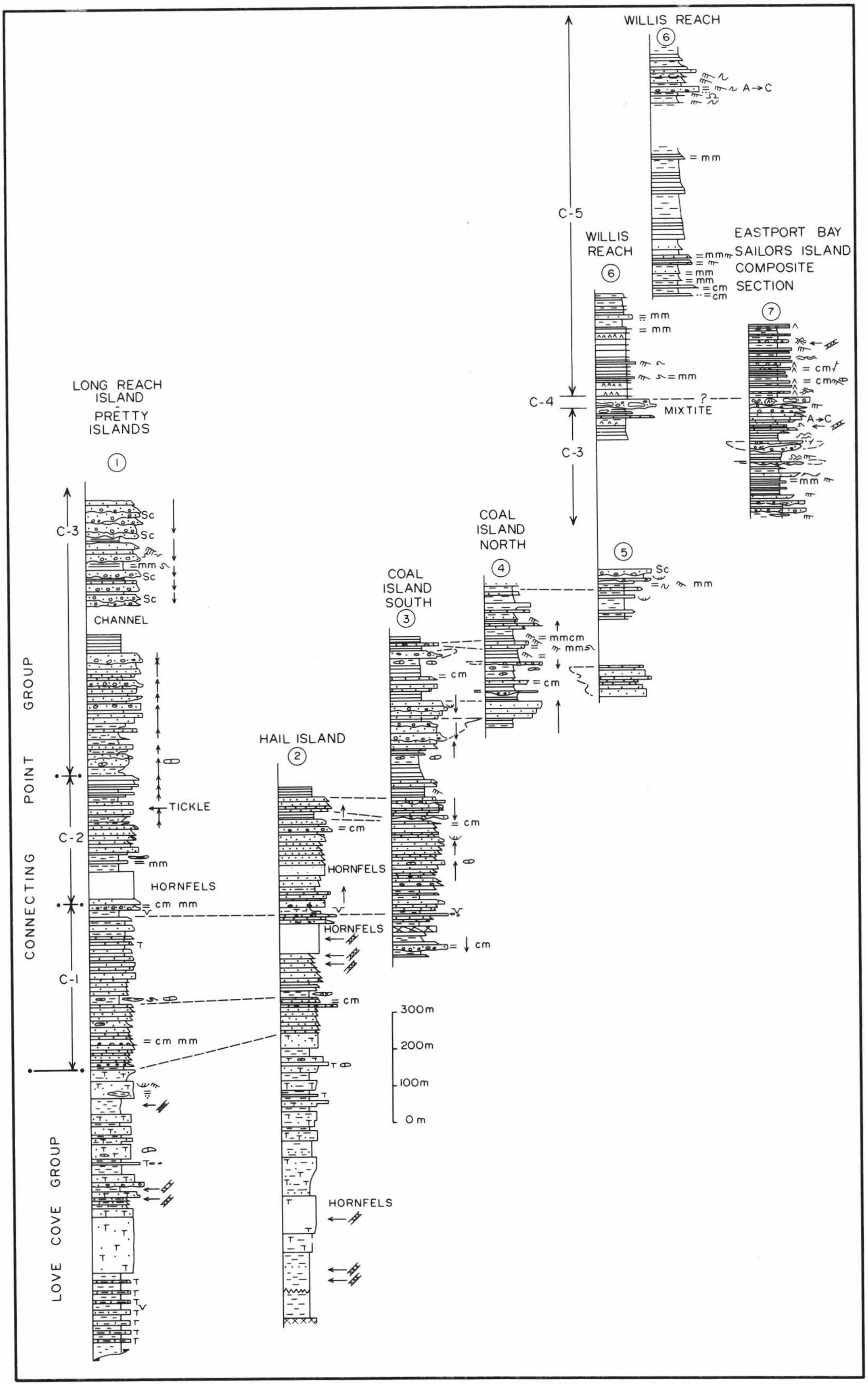



**Figure 3.** *Graphic logs of sections through the Connecting Point Group, Bonavista Bay.*

**KEY** (Figure 3)

- *Siltstone*
- *Shale*
- *Colour-banded siltstone and shale*
- *Thin-bedded sandstone, siltstone and shale*
- *Thin- to medium-bedded sandstone and shale – mostly Bouma $T_a$*
- *Amalgamated graded sandstone – mostly Bouma $T_a$*
- *Thick-bedded sandstone, Bouma $T_a + T_{ab}$*
- *Massive sandstone and pebbly sandstone*
- cm *Planar stratified graded sandstone and siltstone (Facies H)*
- *Mixtite – sedimentary clast*
- *volcanic clast*
- *Chert and siliceous argillite*
- *Siliceous sandstone*
- *Agglomerate*
- *Tuff*
- *Calcareous nodule*
- Fl *Flute cast*
- Gr *Groove cast*
- Sc *Scour*
- *Flame structure*
- *Crosslamination*
- *Crossbed*
- *Convoluted*
- *Slump fold*
- *Sedimentary fault*
- cm *Planar thin stratification*
- mm *Lamination*
- *Syneresis crack*
- *Sand*
- *Pebble and intraclast*
- *Diabase*
- *Coarsening and/or thickening upward*
- *Fining and/or thinning upward*
- A→C *Bouma $T_{abc}$*
- A *Bouma $T_{ab}$*

siltstone and very fine grained sandstone (Plate 1). It occurs mostly in Unit C-3 and C-5. The shale of subfacies A-2 forms the lower part of coarsening- and thickening-upward sequences involving bedded and parallel-bedded sandstone and massive and pebbly sandstone (lithofacies F and G). Subfacies A-3 consists of green-grey shale containing thin interbeds of parallel-laminated siltstone. The rocks have evidence of large-scale synsedimentary slump folding and brecciation, and are associated with slump scars and rotated bedding (Plate 2). They occur in Unit C-5 in close proximity to mixtite of Unit C-4.

*Interpretation.* Black, pyritiferous shales displaying lamination (subfacies A-1) suggest pelagic deposition in anoxic, basinal settings, away from active deep-water submarine fans or active volcanic centres. The shale of subfacies A-2, which is associated with crosslaminated siltstone and very fine grained sandstone, is deposited commonly within upward-thickening and upward-coarsening sequences and is characteristic of deposits of distal regions of submarine fans. The importance of slump features in subfacies A-3 suggests that the shale and thin siltstone represent deposition on the basin slope.

### Lithofacies B: Pyroclastic Rocks and Tuffites

*Description.* Fine grained vitric tuff, fine- to coarse-grained lithic tuff, volcanic breccia and conglomerate are a significant, though minor, component of the basal part of the Connecting Point Group. Similar rock types are common in the upper Love Cove Group, where they are arranged in upward-coarsening sequences that begin with shale, pass upward into vitric tuff, and are completed by crystal and lithic tuff. Some sequences are capped by volcanic breccia. Shale (lithofacies A-1) predominates in the lower sequences, but forms equal proportions with tuff in the higher sequences in the Love Cove Group. In the Connecting Point Group, the lithofacies is intercalated with shales (subfacies A-1) or within turbidites of facies F; no textural sequences are obvious.

Generally the vitric tuffs are microcrystalline, green-grey and characteristically form planar, thin beds containing microflame structures and small-scale cracks preserved locally at the base. Internally, the beds are either structureless, graded, laminated or deformed. The deformed beds exhibit either a swirled texture defined by either microcrystalline or silty tuff, or a distinctive texture marked by blebs of the silty tuff set in a glassy matrix. Some siliceous, fine grained beds intercalated with the tuffs display locally convoluted crosslamination, load casts at the base and distinct normal grading accompanied by massive to laminated structure.

Lithic tuffs are composed of quartz, feldspar and fragments of tuff and shale. Some beds resembling fine grained, pebbly mudstone contain fragments suspended in

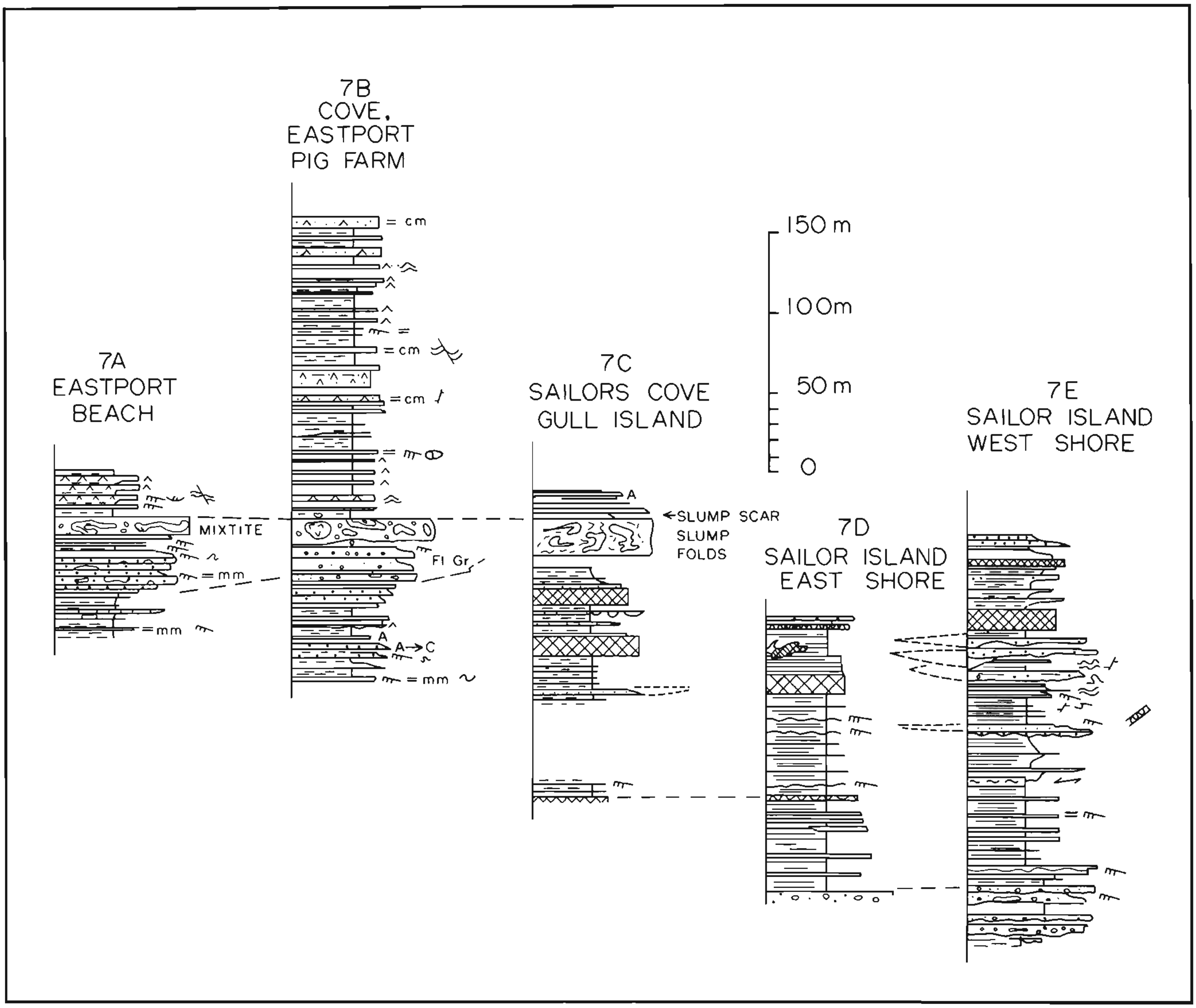



**Figure 4.** *Graphic logs of sections through units C-3 to C-5 in the Eastport Bay and Sailors Harbour area; see Figure 3 for key.*

an unsorted, finer grained matrix. Feldspars are either euhedral, flattened or bicuspate. Depositional fabrics are rarely preserved in the lithic tuffs, although inverse grading is locally developed.

Volcanic breccia and agglomerate occur in massive beds up to several metres thick. The beds have sharp bases and tops, unsorted grains, and normal and inverse grading; some beds change upward from massive to planar stratified. Locally, both rock types contain tuff and shale clasts up to 12 cm in diameter.

*Interpretation.* The intercalation of the tuffs and agglomerates with pelagic shales suggests that they are submarine pyroclastic rocks that accumulated in a basinal setting adjacent to one or several, explosive volcanic centres. The upward-coarsening nature of the sequences and the succession in the top of the Love Cove Group as a whole suggest that the basin fill accreted in response to repeated episodes of prolonged, increasingly violent volcanic eruptions. Many of the beds in the Love Cove and Connecting Point groups are characterized by structures indicative of density-current activity. The prevalence of internally deformed beds, beds of pebbly mudstone and graded beds with turbidite structure indicate abundant remobilization of the volcaniclastic sediments. Massive remobilization of sediment produced thick volcanic conglomerate and breccia. The suspended shale and tuff intraclasts in unsorted beds, and massive to stratified structure in graded beds suggest that these beds were subaqueous debris flows and turbidites.

## Lithofacies C: Colour-banded Siltstone–Shale

*Description.* This facies consists of white-weathering, grey siltstone, green-grey silty shale and black shale that are intercalated in varying proportion through a 250-m-thick

**Table 1.** Sedimentary lithofacies of the Connecting Point and Love Cove groups, Bonavista Bay

| Lithofacies | Characteristic Features | Environment |
|---|---|---|
| A: Shale | A-1: Grey to black; contains silicic laminae; pyrite, thin chert beds and fine grained tuffs | Quiet basinal |
| | A-2: Grey to black, contains lenticular and crosslaminated siltstones | Slope deposits; distal turbidites |
| | A-3: Green-grey with thin parallel laminated siltstone; abundant slump folds, breccias, scars and rotated bedding | Slope deposits |
| B: Pyroclastic sediments and tuffites | Fine grained, schistose, locally auriferous, vitric tuff, quartz-crystal tuff, lithic tuff and volcanic breccia and conglomerate; displays crude coarsening upward sequences | Associated with shale —quiet basinal setting, significant sediment gravity-flow deposits |
| C: Colour-banded siltstone—shale | Grey and green-grey, laminated and planar-bedded siltstone interbedded sharply with black shale | Slope sediments distal turbidites ? |
| D: Thin-bedded siliceous argillite, siltstone and shale | Planar, thin, laminated, crosslaminated and locally convoluted beds; fissure cracks; commonly thin units and intercalated with massive sandstone | Distal turbidites or locally abandoned fan-lobe channel |
| E: Thin-bedded very fine grained sandstone, siltstone and shale | E-1: Centimetre-scale, laminated or crosslaminated sandstone and siltstone, sharply interbedded with shale; some crosslaminated, 15-30 cm thick, very fine grained sandstone at base of fining-upward sequences up to 15 m thick; rare scours. | Distal levee |
| | E-2: Similar to E-1, but with common small-scale slump folds, faults, and convolutions; associated with tongues of massive sandstone and laterally with massive sandstone sequences | Near channel levee |
| F: Parallel-bedded sandstone—shale (in crude to well-developed coarsening upward and fining-upward sequences) | F-1: Metre-thick sequences of planar-bedded, thin- to medium-bedded, medium- to very fine-grained sandstone; generally structureless, but with some parallel lamination; sharp or gradational top with shale. | Mid fans and fan-lobe turbidites |
| | F-2: Crosslaminated and convoluted, very fine grained sandstone and shale | Outer fan turbidites |
| G: Thick-bedded, massive sandstone and pebbly sandstone; rare conglomerate | G-1: Thick-bedded, structureless sandstone; some amalgamated beds; contains intraclasts; graded from very coarse to fine grained. | Proximal turbidites and fan lobe channels |
| | G-2: Amalgamated, scoured, metre-thick beds of very coarse grained to granular sandstone; massive to planar-stratified, rarely crossbedded, crosslaminated, and convoluted. | Inner fan channels |
| H: Graded planar-stratified sandstone, siltstone and shale | Very thick; stratification throughout or may possess a thin basal massive interval; fining upward with intraclasts at base; locally convoluted and commonly interbedded with shale; locally occupy channels. | Crevasse splay, bypass fan lobe, deposited by mass emplacement |
| I: Mixtite | Pebble- to boulder-sized sedimentary lithoclasts (especially of facies D to F) plus rare to locally abundant mafic to felsic volcanic and plutonic detritus; folded blocks; chaotic to oriented fabric; matrix of granular to sandy mudstone; locally associated with facies G-2, and slump-folded sediments above; areally extensive in east area. | Olistostrome<br>Inner channel deposit |
| J: Bedded chert and siliceous argillite | White to grey and black, stratified; units are thick, and locally preserve original sedimentary structure; slump folds are common. | Diagenetic for most part |

Note: Lithofacies A-1, B, D and F are found in both Love Cove and Connecting Point groups. All other lithofacies occur within the Connecting Point Group.

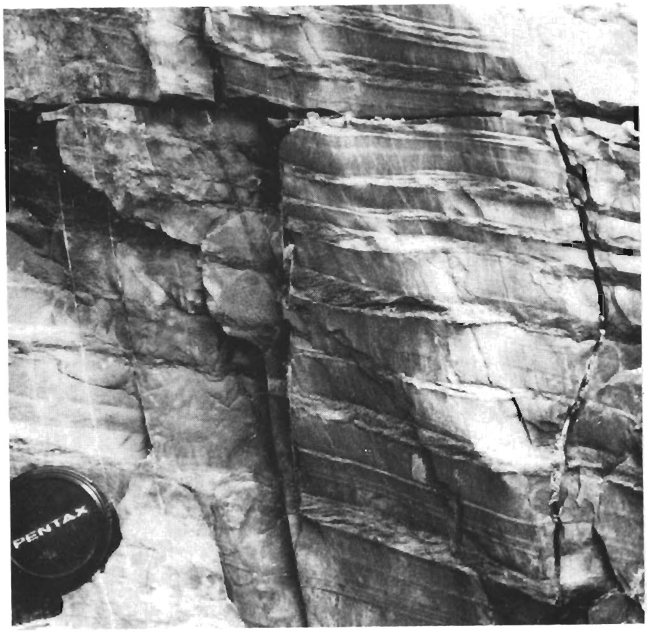


**Plate 1.** *Black shale of subfacies A-2 containing thin, crosslaminated, very fine grained sandstone (Unit C-4), Eastport Bay.*

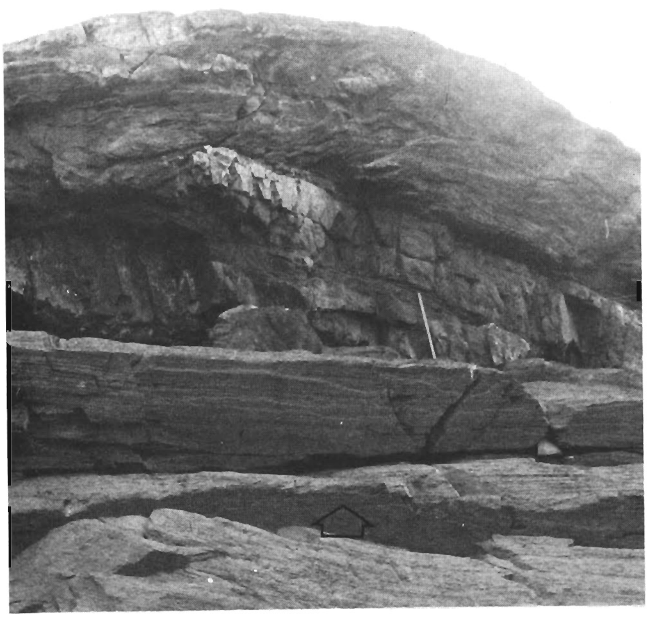


**Plate 2.** *Thin-bedded, green-grey shale and siltstone of subfacies A-3 overlain by a thickly slumped unit involving shale and bedded chert. Note the slump scar (arrow) truncating upturned bedding in the shales. Cuckolds Point, Sailors Harbour; scale is 1 m long.*

section on an island in Willis Reach. The facies is characterized by green-grey silty shale and black shale couplets, a few centimetres thick, which are intercalated with thin beds and laminae of white-weathering, grey, laminated siltstone to fine grained sandstone (Plate 3). Each of the three

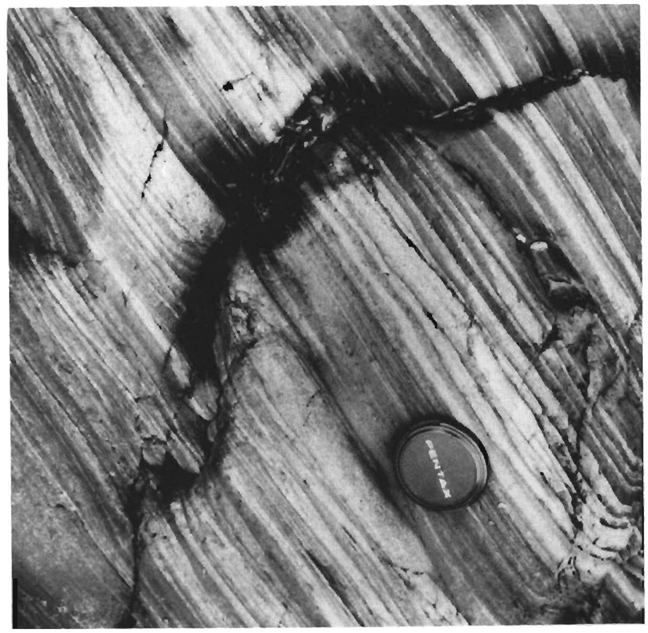


**Plate 3.** *Colour-banded siltstone and shale lithofacies with major sandstone component; island in Willis Reach.*

rock types may predominate in intervals up to 70 cm thickness within the sequence. The lithofacies occurs in Unit C-5.

*Interpretation.* The thin-bedded shale couplets are interpreted to be pelagic and hemipelagic deposits that were deposited on a slope, and sheltered or distal areas of the basin. The lack of slump features in this facies does not preclude a slope setting, since stable slopes are documented in recent reviews of continental slope and rise sediments (Cook *et al.*, 1982). The thin, sharply interbedded siltstones and sandstones are thin deposits of bottom currents.

### Lithofacies D: Thin-bedded Siliceous Argillite, Siltstone and Shale

*Description.* This facies has a limited distribution relative to others in the group and occurs as less than 1-m-thick units within thick sandstone intervals (lithofacies F and G) in Units C-1 and C-2. The argillite–siltstone is thin-bedded, laminated and crosslaminated and contains convoluted structures in many places. Thin beds and partings of shale separate the siltstone beds.

*Interpretation.* The fine grained, thin-bedded rocks of this facies are interpreted as thin turbidites that were deposited on temporarily abandoned fan lobes and lobe channels (also see lithofacies F).

### Lithofacies E: Thin-bedded, Very Fine Grained Sandstone, Siltstone and Shale

*Description.* Rocks of this lithofacies form units up to 100 m thick, characterized by planar and laterally persistent, centimetre-scale beds, arranged in 3-m- to 18-m-thick, fining-upward sequences (Plate 4). They form a significant part of

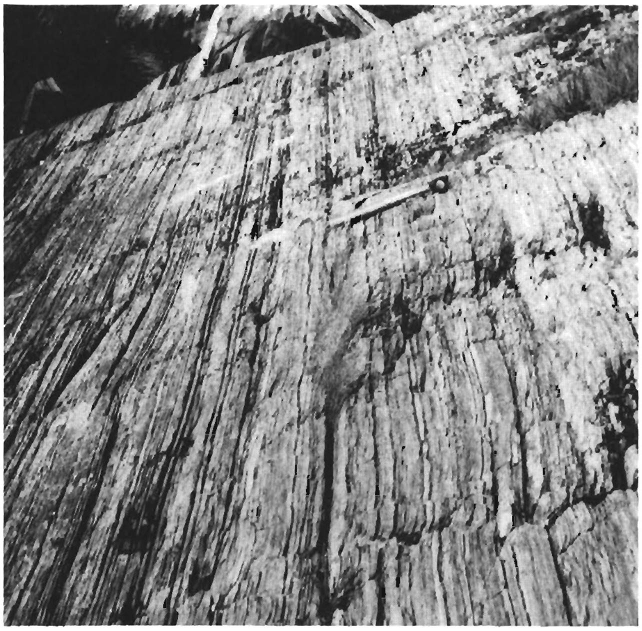


**Plate 4.** *Thin-bedded siltstone and shale of lithofacies E from the top of a fining-upward sequence on Coal Island; beds dip steeply to the left. Hammer is 33 cm long.*

**Plate 5.** *Channel scour (arrows) at base of massive sandstone (facies G) marking erosion into proximal sediments of facies E. Note the sandstone bed intercalated with the thin-bedded facies below the channel; western shore of Sailors Island.*

Unit C-3, where they are intercalated with lenticular units of massive sandstone (see lithofacies G below).

Each sequence (subfacies E-1) begins with a fine- to very fine-grained sandstone bed that is rarely more than 60 cm thick. The sandstone is commonly crosslaminated and convoluted above a sharp to locally scoured base. Above the basal bed, the sequence continues with thin-bedded, crosslaminated, very fine grained sandstone and coarse siltstone containing shale partings. Upward in the sequence, shale interbeds thicken and occur in equal proportion to the coarser grained rocks (Plate 4); the top few metres of a sequence may consist entirely of black shale.

In the western limb of the Willis Reach syncline, discontinuity surfaces such as slump scars are apparently absent. Crosslaminated sandstone forms 10- to 20-cm-thick interbeds in the the lithofacies below intercalated units of massive sandstone (see lithofacies G, below).

On Sailors Island, near Salvage, 20-cm- to 40-cm-thick beds of structureless, very coarse- to fine-grained sandstone and intraclastic, sandy mudstone intertongue in the thin-bedded lithofacies (subfacies E-2) adjacent to the channel-bounding, lithofacies G sandstone (Plate 5). Individual sandstone tongues are, in most places, scour based and contain shale rip-ups. Massive beds of coarse grained sandstone are traceable along strike into crossbedded or crosslaminated, fine grained sandstone. The host thin-bedded facies consists of thin to locally 30-cm-thick, beds and lenses of coarse- to very fine-grained sandstone, interbedded unsystematically with shale units of equal thickness. The sandstone is consistently crosslaminated. The thin-bedded facies is also characterized by the presence of the following features:

1) small slump folds (Plate 6) that have north-northeast- to east-northeast-trending axial planes that dip shallowly to steeply eastward,

2) local slump breccia,

3) small slump scars, and

4) small-scale synsedimentary faults.

The above association occurs on the western shore of Sailors Island. In contrast, 500 m eastward, on the eastern shore of the island, synsedimentary deformation is virtually absent. There, the succession (subfacies E-1) consists of rhythmically interbedded thin sandstone and shale (Plate 7), interrupted only rarely by single, thick, coarse grained sandstone beds. The thin sandstones are, for the most part, very fine grained, sharp based and sharp topped, and internally crosslaminated. Locally, the thin sandstones form graded beds that are either massive to laminated or laminated to crosslaminated with basal load casts.

*Interpretation.* The association of lithofacies E with units of channeled sandstone (lithofacies G) indicates that there is a genetic relationship between the two facies. The thin-bedded facies is interpreted to have been deposited as levees adjacent to channels. The proximal levee deposits are characterized

**Plate 6.** *Soft-sediment deformation in thin-bedded, laminated sandstone and shale of facies E; western shore of Sailors Island.*

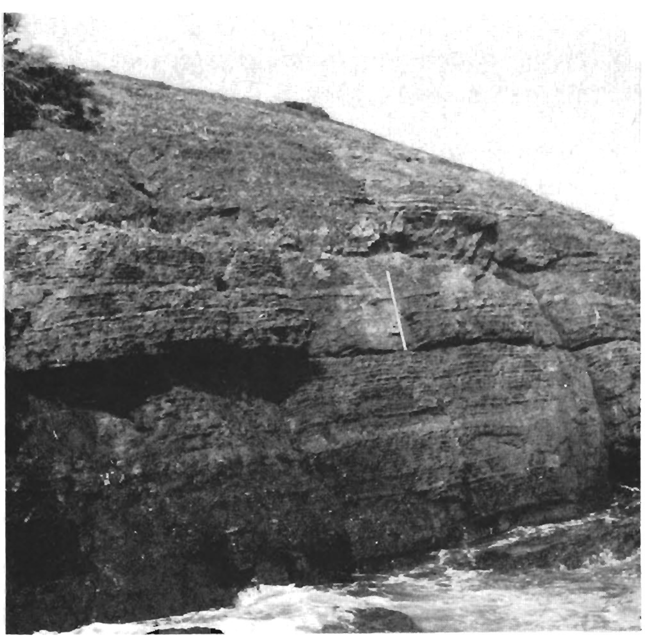


**Plate 7.** *Rhythmic interbedding of shale and thin sandstone, distal levee sediments of lithofacies E; eastern shore of Sailors Island. Scale is 1 m long.*

by sandstone of variable grain size, abundant synsedimentary deformation, and crosslamination that is directed away from the channels. The distal levee deposits are rhythmically bedded and generally free of soft-sediment deformation as seen on the eastern shore of Sailors Island. The fining-upward sequences exposed on the western limb of the Willis Reach syncline are interpreted as the probable response of overbank sedimentation to lateral channel migration or gradually silting up of the channel with time.

### Lithofacies F: Parallel-bedded Sandstone–Shale

*Description.* Lithofacies F is especially well developed in the lowest two stratigraphic units of the Connecting Point Group. It is characterized by laterally continuous, parallel-bedded, thin- to medium-bedded, medium- to very fine-grained sandstone (Plate 8). Thick-bedded sandstone occurs as either single beds or groups of beds. The sandstone beds have sharp, planar bases, and are internally structureless; they grade up into shale. Thicker sandstone beds are, in most places, massive; some display planar, thin stratification and lamination toward their top. A few beds display crosslamination at the top.

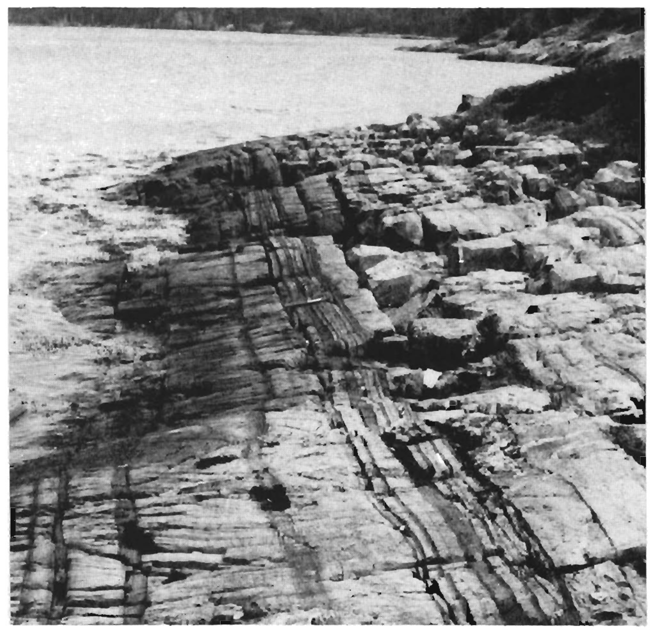


**Plate 8.** *Thin- and medium-bedded sandstone and shale of facies F, Hail Island; beds dip steeply to right.*

Thin-, medium- and thick-bedded sandstones are commonly amalgamated. Amalgamation (Plate 9) is recognized by the presence of coarser grained sandstone layers, which include euhedral and flattened feldspar grains, and also by the presence of either slivers of shale or bedding-parallel zones of elongate shale fragments, suspended in the sandstone bed. In some instances, zones of shale clasts can be traced into a shale interbed that separates sand beds. Calcareous concretions locally cement the sandstones.

This lithofacies also occurs in the shale-dominated lithostratigraphic units above and below the mixtite near Eastport and Salvage, where thickening- and coarsening-upward sequences are exposed. Individual thin sandstone beds are typified by laminated to crosslaminated divisions above planar bases. Medium-bedded sandstones include a massive division alone (top photograph, Plate 14), or there is an accompanying laminated and, rarely, crosslaminated division. Thick sandstone beds at the top of sequences have thick,

**Plate 9.** *Amalgamated beds of facies F, Coal Island. Note the flat shale intraclast and layer of coarse, light-weathering feldspar grains in the middle of the bed.*

massive divisions, overlain by laminated and convoluted crosslaminated divisions. Flute and groove casts occur on the planar bottoms of thick beds, which are locally deformed by loads. Small pebbles and shale rip-ups occur in the massive divisions of some thick beds.

*Interpretation.* The bedded sandstones of lithofacies F have all the characteristics of turbidites. The planar laminated and crosslaminated, thin sandstones exhibiting planar bases and good lateral continuity are distal turbidites deposited, for the most part, on the outer part of a submarine fan. Midfan and inner, fan-lobe settings are envisaged for the medium-bedded and thick-bedded sandstones that are characterized by sharp, planar bases, laterally continuous bedding, grading and massive division A of the Bouma sequence. The presence of well developed, upward-coarsening- and upward-thickening sequences is indicative of prograding fan lobes.

### Lithofacies G: Thick-bedded, Massive Sandstone and Pebbly Sandstone

*Description.* The sandstones of this facies are distinguished by their very coarse- to fine-grain size and by their massive, thick-bedded, graded nature. The facies is a significant part of Unit C-3, but is also found in Unit C-2. Two distinctive sandstone subfacies are distinguished.

Sandstones of subfacies G-1 form 80-cm- to 1.5-m-thick beds that have good lateral continuity. They occur in units up to 95 m thick at the top of coarsening- and thickening-upward sequences involving turbidites of lithofacies F. Fine grained sandstone beds that occur at the base of these units give way to very coarse grained beds at the top of the units.

Each bed typically has a planar, sharp base overlain by graded, otherwise structureless sandstone, which in some thicker and coarser beds, is superseded by planar stratified sandstone. Shale intraclasts up to 10 cm in size occur in the massive division of the coarser grained sandstone beds.

Granular, intraclastic, pebbly sandstone forms subfacies G-2. These rocks commonly overlie subfacies G-1 sandstone where the latter first appears in the stratigraphic column. Subfacies G-2 units are 15 m to 95 m thick. Upward, the pebbly sandstone units are much thicker and are intercalated with fine grained, thin-bedded rocks of lithofacies E. Locally, erosional channels downcut several metres into the finer grained sediments. On Sailors Island, the scour has a step-like shape traceable into the channel (Plate 5). Within individual units, there are several major scour surfaces, each overlain by very coarse grained, pebbly sandstone that fines upward. Overall, the units also fine upward. Comparison of logs of adjacent sections suggests that the thickness of the sandstone beds varies from section to section and that some thin and pinch out.

The sandstone beds are between 1.5 m and 4 m thick. In general, the massive division of the bed (Plate 10) is overlain by graded, planar-stratified and locally convoluted sandstone that forms the upper half of the bed. In places, 25-cm-thick, trough cross-sets are present; locally, the uppermost part of the bed has convoluted crosslamination. Load casts and flames deform basal scours, and intraclasts, commonly imbricated, are concentrated close to the base of the bed. Locally, folded slabs of shale and thin-bedded sediment of lithofacies E, up to 1 m by 25 cm in dimension, are common in the scour-bound sandstones.

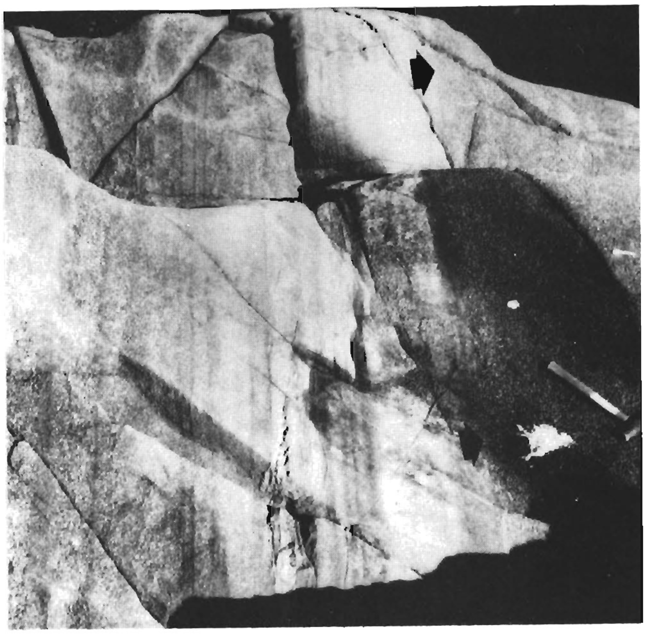


**Plate 10.** *Stratified and massive sandstone of facies G-2 separated by a scour (arrow), Pretty Island.*

*Interpretation.* The graded, massive, thick-bedded sandstones of subfacies G-2 display the characteristics of proximal, Bouma $T_a$ and, less commonly, $T_{a-b}$ turbidites, and are closely comparable to facies $B_2$ of Walker and Mutti (1973). The graded, massive nature suggests that they were deposited rapidly from suspension (Middleton and Hampton, 1976). This may also suggest that they were deposited from grainflows, although they lack inverse grading that is characteristic of these types of flows (Walker, 1984). These turbidites are characterized by: 1) sharp planar bases, 2) lateral continuity, and 3) upward coarsening within units. These features, coupled with the stratigraphic position of the turbidites above coarsening- and thickening-upward sequences, suggest that deposition occurred on the inner fan. The sharp bases and lack of channeling in the thick, massive sandstone indicate that it represents deposition on the fan lobe, either near distributary channel mouths or in a network of broad and shallow distributary channels.

The sandstones of subfacies G-2 fine upward and occur in lenticular, scour-bounded units, and are thus interpreted as channel deposits. The presence of the following features in these rocks indicate that they are channel deposits of deep-water submarine fans (Walker, 1978, 1984): 1) abundant scours, 2) coarse grained, graded sandstone, rich in intraclasts derived from erosion of associated levee sediments (lithofacies E), 3) locally channeled contacts with lithofacies E, and 4) massive to stratified, sedimentary structures associated with locally crossbedded and convoluted structures at the top of some beds. The lenticular distribution of these channel sand bodies suggests that they periodically switched their position on the fan by avulsion.

### Lithofacies H: Graded, Planar-Stratified Sandstone, Siltstone and Shale

*Description.* This lithofacies most commonly occurs as single units, up to 14 m thick, intercalated within thin-bedded turbidites (lithofacies F) in the basal 500 m of the Connecting Point Group. Similar units occur within shales of lithofacies A and D in stratigraphic Units C-1, C-2 and C-5. One scour-based sandstone, 1.7 to 3.7 m thick, assigned to facies H fills a channel, 1.8 m deep and more than 30 m wide (Figure 5) in facies E rocks on Coal Island.

Where they are intercalated with turbidites of lithofacies F, the units are always graded. Individual beds have a scoured base overlain by an intraclastic, very coarse grained, tuffaceous sandstone that grades through very fine grained sandstone into siltstone. Locally, shale laminae occur at the top. Beds comprise a basal, 25-cm- to 50-cm-thick, shale-intraclastic structureless interval, overlain by a zone of cm-scale planar stratification (Plate 11), and capped by a laminated interval. The thick, stratified interval is composed of strata that display an upward decrease in thickness and grain size. Units are capped gradationally by a shale bed. Where they occur within shales in Units C-1, C-2 and C-5, the beds invariably begin with stratified, medium- to fine-grained sandstone and grade upward into siltstone. Locally, the stratification is disrupted by small-scale, soft-sediment folds and by convolutions.

*Interpretation.* The thick, graded deposits of this facies are interpreted as sediment gravity-flow deposits that occur anomalously in basinal settings (shale facies), on distal parts of deep-sea fan lobes (thin- to medium-bedded turbidites) and in small channels crossing overbank sediments of fan channels. They are distinguished by several features, including: 1) considerable thickness, 2) coarse grain size with shale rip-ups at the base, 3) upward fining, and 4) gradational change within a bed from structureless to stratified. These features indicate that the beds were deposited by thick, highly concentrated gravity flows, whose flow power waned gradually; they compare favourably with megaturbidites (Bouma, 1987). The occurrence of a massive basal interval with suspended shale rip-ups above a scoured base suggests that the sediment was carried into the distal settings by turbidity currents. Howell and Normark (1982) illustrate similiar thick units of very thinly stratified sandstone, which they attribute to mass emplacement. The great thickness of this lithofacies may reflect local ponding of the flows. The association of these rocks with basinal and distal fan lobe lithofacies and the channelized unit in the leveed sediments of lithofacies E suggests that they may be crevasse splay deposits.

### Lithofacies I: Mixtite

*Description.* Mixtite is a nongenetic term (Schermerhorn, 1966) denoting a coarse grained, nonsorted or poorly sorted (mud- to boulder-sized detritus) clastic

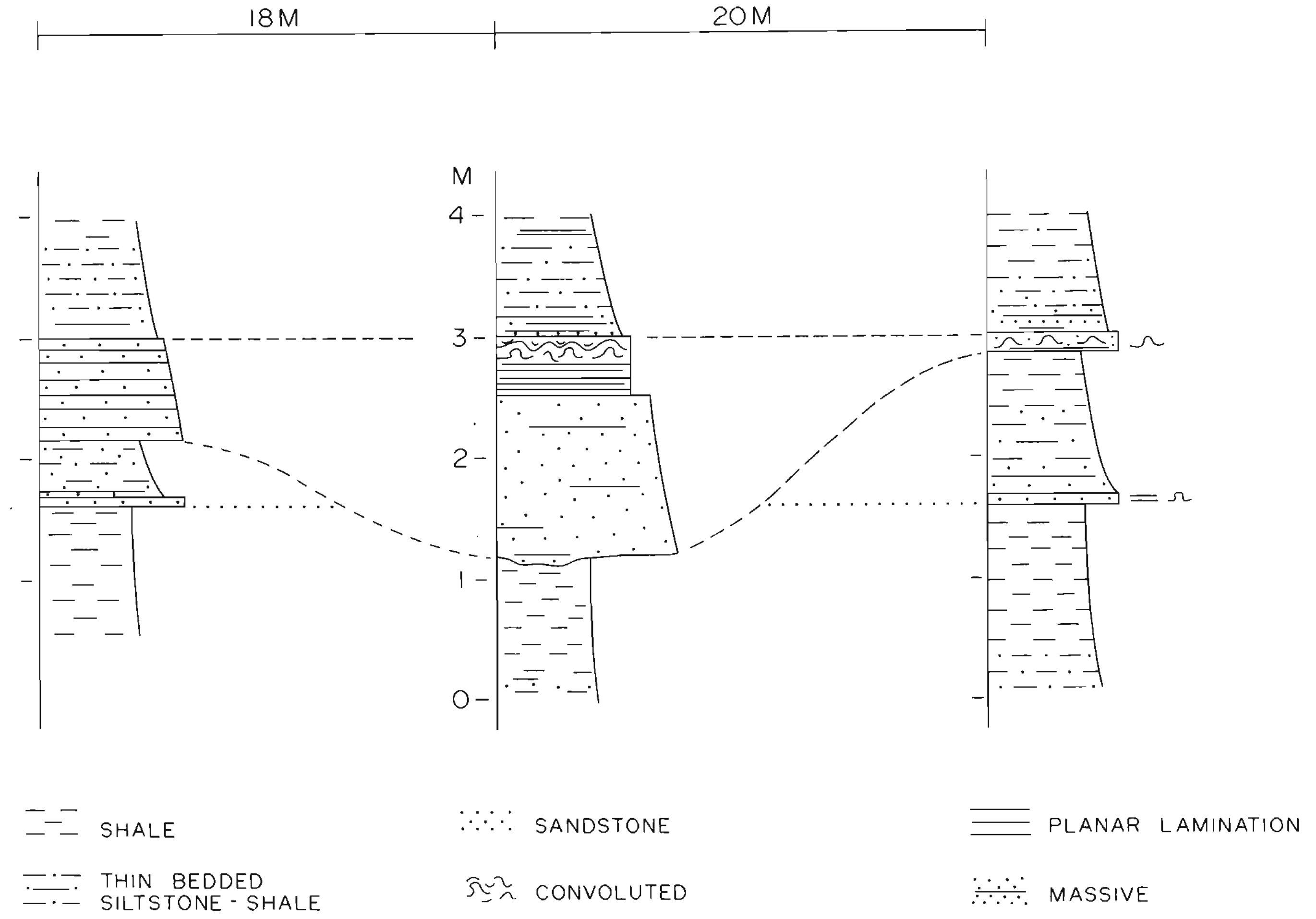



**Figure 5.** *Crevasse channel filled by laterally thinning, graded, massive to stratified sandstone in the north section (4) of Coal Island.*

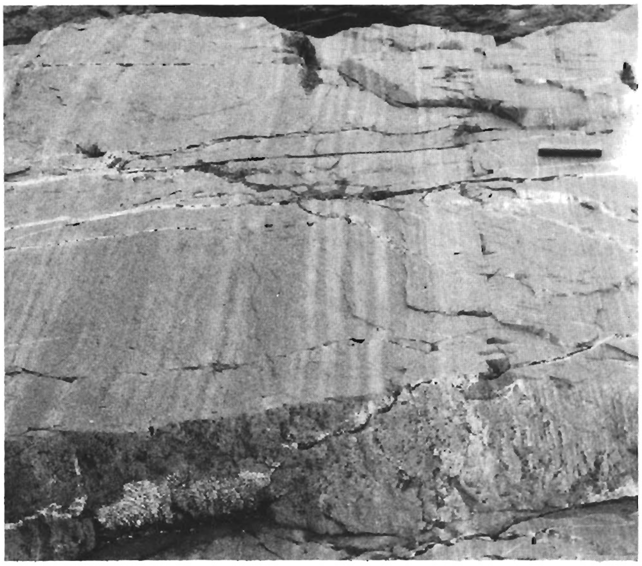


**Plate 11.** *Stratified-graded sandstone of facies H, Hail Island. Note the upward (to right) fining and thinning; scale is 10 cm long.*

sedimentary rock. It is used without regard to composition or origin of the rocks. This lithology forms a very widely developed, thin (11 to 17 m), lithostratigraphic unit (C-4) and lithofacies. The unit forms spectacular strike sections along the southeastern shore of Eastport Bay, and is well exposed near Happy Adventure and on the eastern shores of Willis and Morris islands. It also underlies Flat Islands and many adjacent smaller islands in this part of Bonavista Bay. On the western limb of the Willis Reach syncline, the mixtite is exposed only on one small island, located in Willis Reach. In the Eastport Bay section, the mixtite overlies a coarsening-upward sequence of shale, bedded turbidite and massive sandstone. On Horse Chop Island and Flat Islands, east of Morris Island, it rests abruptly upon variably silicified, thin-bedded turbidite and shale. On Flat Islands and at Cuckolds Head, near Salvage, the mixtite locally strikes laterally into sediments displaying large-scale slump folds and minor synsedimentary brecciation.

The mixtite consists of rafts of sedimentary olistoliths (Plate 12) supported in a brown-weathering, grey, mud- to sand-sized matrix (see Plate 3 of O'Brien and Knight, *this volume*). The sedimentary olistoliths are principally

**Plate 12.** *Mixtite containing deformed sedimentary olistoliths. Base of bed (arrow) is sharp; Eastport Bay.*

composed of shale, thinly interbedded shale and sandstone, bedded sandstone and shale of lithofacies F, and the thin-bedded, fine grained rocks of lithofacies E. Clasts of interbedded shale–chert and massive pebbly sandstone also occur. The olistoliths are invariably long slabs (up to 30 m and thickness up to 5 m) that are recumbently folded into S and Z shapes. In one section at Eastport Bay (grid reference 539395,30035, Eastport map sheet) clasts are chaotic. In another section, 1.5 km to the southwest (grid reference 539315,29955, Eastport map area), however, the clasts are oriented with their long axes trending southeast and their internal bedding dipping between 30 and 75 degrees southwest. Axes of folds in deformed slabs also trend southeast. In the Eastport Bay section, (grid reference 539395,30085, Eastport map area) the mixtite also includes scattered pebbles and blocks of felsic volcanic rocks and chert. The volcanic clasts are lithic tuff and agglomerate, quartz–feldspar porphyry, spherulitic rhyolite, vitric tuff and white and red silicic tuff. On Flat Islands, the mixtite contains more volcanic debris including pebbles of diabase. In general, the pebbles are up to 10 cm in diameter and subrounded. The largest volcanic block (Plate 13) occurs in the Eastport Bay section (grid reference 539395,30085, Eastport map area); it is approximately 13 m across.

The mixtite has a sharp, locally erosive, base. In some areas (e.g., Eastport Bay) the material comprising the mixtite bed ceased movement as it wedged up underlying sediment. In the same section, underlying bedding is buckled and locally thrust onto itself.

*Interpretation.* The mixtite is a massive, sediment gravity-flow deposit of regional significance derived largely by mobilization of sediments of the Connecting Point Group. This implies that it is a mass flow deposit caused by failure of unconsolidated sediment. That the mixtite can be traced laterally into slump-folded sediments locally associated with slump scars indicates that the mass flow deposit originated at the basin slope. At present, there is insuffcent stratigraphic data to establish if there is more than one major mixtite sheet.

The proportion of incorporated felsic and mafic igneous detritus increases within the mixtite northeastward across the area. The occurrence of the 13-m block of lithic tuff and agglomerate in one section at Eastport Bay is anomalous to this general trend. Diabase pebbles are apparently localized in the area of Flat Islands. The diabase is believed to be derived from dykes that intruded wet sediments (O'Brien and Knight, *this volume)* and are common in the same area. This would mean that at least some of the plutonic detritus is locally derived. The felsic volcanic detritus, however, has a less localized source and may have been derived by erosion of the Love Cove Group or by resedimentation of mixtite that is perhaps equivalent to the lithologically similar Gaskiers Formation of the eastern Avalon Peninsula (Williams and King, 1979; King, *in preparation).* The anomalously large block described above may be a resedimented erratic transported from the shelf during slope failure.

### Lithofacies J: Bedded Chert and Siliceous Argillite

*Description.* Thin, structureless, off-white and grey chert is interbedded with black shale near the base of the Connecting Point Group. In contrast, thick beds of brown-weathering, off-white to black chert and siliceous argillite are interbedded with shales and turbidites in the section above

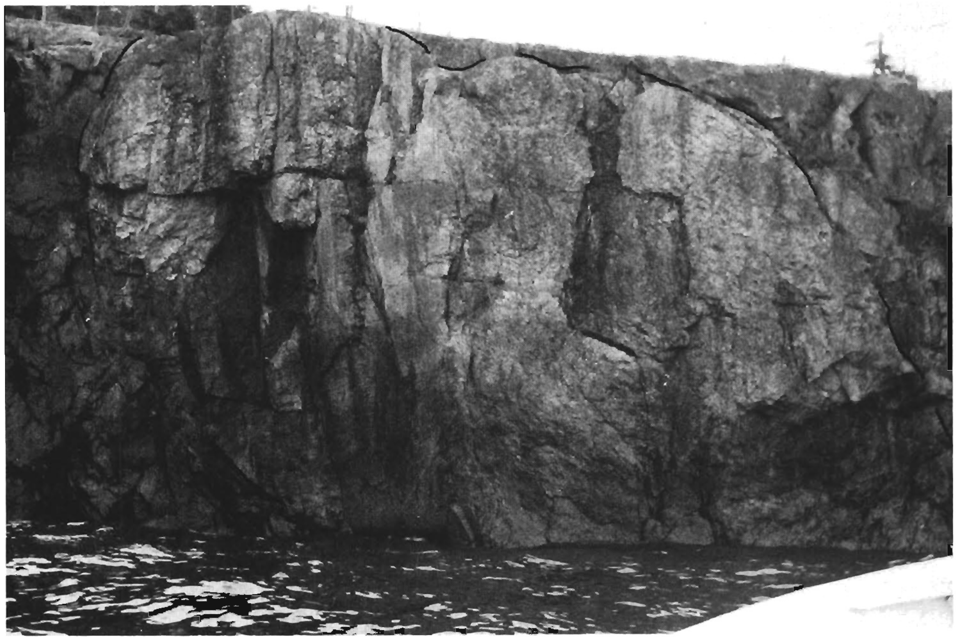


**Plate 13.** *Block (13 m across) of felsic tuff and agglomerate in the mixtite, Eastport Bay.*

and below the mixtite. The beds are up to 10.5 m thick and display the following sedimentary structures: 1) crosslamination, 2) planar lamination, 3) very thin stratification, 4) grading, 5) small-scale convolution, and 5) larger-scale synsedimentary buckling and thrusting.

*Interpretation.* The abundance and type of sedimentary structures within the chert and argillite indicate that these rocks are silicified sandstone and siltstone. The chert is interpreted as a diagenetic facies. The presence of chert pebbles of similar colour in some of the coarser grained, pebbly sandstone and mixtite, indicates that the chert formed just beneath or on the sea floor, soon after the original sediment was deposited. Similar cherts above the mixtite probably also formed at or just beneath the sea floor.

## DISCUSSION

### Basin Fill

The upper 800 m of the Love Cove Group and the overlying Connecting Point Group in the Eastport area record four stages in the evolution of a major late Precambrian depositional basin, here named the Eastport basin.

*Stage 1.* The first stage primarily involves the accretion of subaqueous, silicic, dominantly pyroclastic sediments (lithofacies B) in a basinal setting in which pelagic muds (subfacies A-1) accumulated. The presence of shale and lithic volcanogenic fragments in the coarser grained pyroclastic rocks, the occurrence of volcaniclastic debris flows, the intercalation of turbidites and tuffs containing internal deformation, all suggest abundant submarine reworking of the volcanic rocks in the basin. The silicification of volcaniclastic rocks of lithofacies B within the underlying Love Cove Group points to local hydrothermal activity at this time.

*Stage 2.* The deposition of 1600 to 1800 m of sandy turbidites derived from erosion of a volcanic edifice marks the second stage of basin fill. Although the sequence consists of sandstone that coarsens upward overall, it is divisible into at least two distinct parts; viz., a lower section 600 to 850 m thick, predominated by thin- to thick-bedded sandy turbidites, and an upper section (up to 1000 m thick) of channeled massive sandstone and pebbly sandstone associated with widely developed levee-facies- or overbank-facies shales and sandstones. The lower section probably preserves the deposits of lower fan and midfan (Walker, 1984); the upper section represents the levee-channel complex of the channeled inner fan (Walker, 1984, 1985).

The sequence deposited in stage 2 is interpreted to represent basinward progradation of the fan; the lower part of the Connecting Point Group (e.g., below mixtite) broadly fits the deep-water fan model of Walker (1978, 1984) and Normark (1978). The succession of these bedded turbidites, however, is not composed of classical turbidites arranged in well-developed upward-thickening and upward-coarsening progradation sequences of distal Bouma $T_{bce}$ to proximal Bouma $T_{abe}-T_{ae}$ turbidites. Instead, it consists mostly of massive, graded, very fine- to medium-grained sandstone that was deposited rapidly by high-density flows.

The abundance of well-sorted sandstone and the poor development of Bouma sequences and of fining- and coarsening-upward sequences suggest that the deep-water fan was a low efficiency type (Howell and Normark, 1982; Walker, 1984). Howell and Normark (1982) report that abundant sand influx tends to produce shorter and less elevated leveed valleys on the inner fan. It also results in the association of units of medium- to thick-bedded, sandy turbidite bundles with thin-bedded turbidites or hemipelagic sediments, similar to those seen at the base of the Connecting Point Group. The poor sequence development in the sandy pile, however, may reflect interference of more than one source, especially in a relatively narrow basin. It is noteworthy that: 1) poorly developed deep-sea fans are common in volcaniclastic aprons that fill marginal basins of active volcanic arcs (cf. Sigurdsson *et al.*, 1980; Carey and Sigurdsson, 1984) and 2) sediment gravity-flow deposits may make up to 77 percent of these aprons (Sigurdsson *et al.*, 1980; Fisher and Schmincke, 1984).

The importance of levee deposits associated with lenticular channeled sandstone (Unit C-3) higher in the group suggests that the inner part of the fan hosted a well-developed, leveed-channel complex. This may indicate that the efficiency of the fan improved with time, so that there was greater differentiation of the sediment supplied to it.

*Stage 3.* The mixtite and overlying shale, together with colour-banded shale and siltstone characterized by locally abundant disturbed bedding, are diagnostic of the third stage in the basin fill. The shales are arranged, locally with thin- to medium-bedded turbidites, into coarsening-upward sequences near the top of this part of the succession. In general, however, sandstone is unsystematically distributed in the shale. The colour-banded shales and siltstones are interpreted to represent pelagic and hemipelagic slope deposits in which the terrigenous component is quite pronounced. The presence of mixtite and the laterally equivalent slump deposits near the base of this interval support a base-of-slope setting. Slumps of local origin and small downslope displacement of beds contrast with the mixtite, which is interpreted to be a mass-flow deposit that transported not only rafts of bedded sediments, but also volcanic and plutonic debris derived from elsewhere within or outside the basin.

*Stage 4.* The latest stage of basin development recorded in the map area involves the deposition of an upward-coarsening succession (approximately 1 km thick) of repeated upward-thickening and upward-coarsening sequences of thin-bedded distal to medium-bedded, more proximal, turbidites (Plate 14). The occurrence of these rocks indicate that this part of the succession is built of overlapping prograding fan lobes of the classical deep-sea fan model (Walker, 1984). The turbidites deposited in this stage show the structures associated with classical turbidites. It is premature to conclude, without the necessary petrographic support, that these differences reflect the development of a second generation of deep-sea fans that overlapped the earlier basin fill. Similar classical turbidites occur at the base of the Connecting Point Group section in the Placentia Bay area, where they underlie a deltaic sandstone–shale sequence and fluvial(?), pebbly sandstones and conglomerates (O'Driscoll and Muggridge, 1979). Mapping in the east half of the Eastport map area (O'Brien, 1987) indicates that the turbidites of stage 4 are very extensive in the higher stratigraphic portions of the group exposed in that region.

### Correlation with the Conception Group

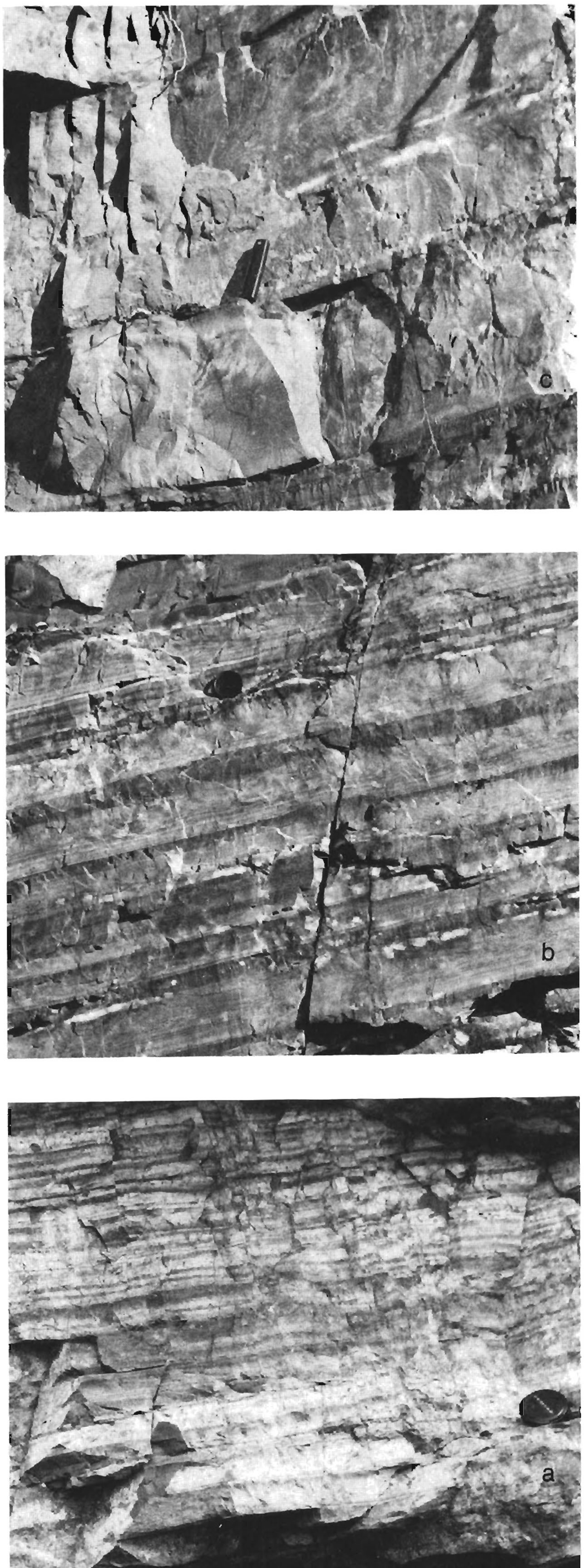
The Connecting Point Group is considered by many authors to be the chronostratigraphic and lithostratigraphic equivalent of the Conception Group (Rose, 1952) of the Avalon Peninsula (e.g., Buddington, 1919; Hayes, 1948; Jenness, 1963; McCartney, 1967). Although the two groups share a roughly common stratigraphic position above the main massifs of Avalonian volcanic rocks and below Avalonian molasse, it is not known if both successions were deposited in the same basin. However, certain broad similarities within the successions are apparent.

Significantly, both groups contain mixtites. In the Conception Group, evidence of a glacigenic origin for these rocks is recorded (e.g., Anderson and King, 1981). No such evidence has yet been recognized in the Connecting Point Group mixtite, but the remarkable lithological similarities of the mixtites, and their common occurrence beneath thick sequences of classical turbidites, supports crude regional correlation. The Mall Bay Formation (Williams and King, 1979) and the Broad Cove River Member of the Drook Formation (King, *in preparation)* of the Conception Group and the St. Phillips Formation of the Harbour Main Group (King, *in preparation)* may contain rocks stratigraphically equivalent to the premixtite portion of the Connecting Point Group. More data from both the Connecting Point and Conception groups is required before it is known if either: 1) both successions were deposited at roughly similar latitudes in the same basin and are now separated by faults and infolded younger sediments, or 2) each occupied a distinct basin.

### Tectonic Setting

The Connecting Point Group underlies a southward-narrowing zone 150 km long, which has a maximum width of 30 km in the Eastport area. A succession of flysch, best exposed in the Eastport area and greater than 3.5 km thick, developed in this zone. The occurrence of these rocks, which occupy a stratigraphic position between the Love Cove and Musgravetown groups, suggests that a basin of large dimension evolved, filled and was deformed in a relatively short span of geological time (possibly as little as 30 Ma). The genetic and conformable relationship with the underlying Love Cove Group and the abundance of volcanic detritus in the sands of the group support a spatial relationship between the two groups possibly in a volcanic arc-basin setting. Volcanic rocks of the Love Cove Group in the Eastport area are of calc-alkali affinity (Hussey, 1979). The Connecting Point sediments of the Eastport basin are a volcaniclastic basin fill that were derived by erosion and reworking of flows, pyroclastics and epiclastic sediments of contemporaneous volcanic islands that surrounded the basin.

The alternating juxtapositioning of the volcanic and sedimentary belts within the Avalon Zone seen in the regional geological map of the zone (Figure 1) is highlighted by the regional aeromagnetic data of Haworth and LeFort (1979).




The offshore magnetic data indicate this pattern holds for the entire extent of the Avalon Zone north of the Collector Magnetic Anomaly (Haworth and LeFort, 1979), eastward to the continental margin. Although some structural modification of the original pattern has undoubtedly occurred, the absence of intense deformation affecting the terrane and the presence of regional unconformities between the Love Cove—Connecting Point groups and younger Precambrian and Lower Cambrian strata suggests that the pattern of alternating magnetic highs and lows, which corresponds on land to volcanic—plutonic and sedimentary successions, respectively, may in part, reflect the original late Precambrian configuration of linked volcanic ridges and sedimentary basins. The western limit of the Eastport basin, for instance, roughly marks the original western limit of an extensive marine basin that was situated east of a màjor volcanic terrane. Remnants of this volcanic terrane are preserved in the Love Cove Group and equivalents of the western Avalon Zone. In some modern geological settings, subparallel linear arcs and basins form where repeated arc spreading occurs through the history of an arc margin (Dickinsen, 1974; Carey and Sigurdsson, 1984). A modern example is the eastern margin of the Phillipine plate near the Mariana Trench (Hussong and Uyeda, 1981). The map of linear volcanic remnant and active arcs and sedimentary basins in this area approximately matches the magnetic (reflecting volcanic—sedimentary facies belts) map of the Avalon terrane (Haworth and LeFort, 1979) in both scale and geometry.

The volcaniclastic sediments of the Eastport basin and the succession outlined above (see Basin Fill section) bear some similiarities to a model for sedimentation in marginal arc basins synthesized by Carey and Sigurdsson (1984). For instance, pelagic muds, pyroclastic flows and dominantly mass flow epiclastic deposits displaying hydrothermal alteration, characterize the initial rifts of volcanic arcs. Rocks of the upper part of the Love Cove Group and perhaps the lower part of the Connecting Point Group (Unit C-1) have these characteristics. Initially, rift basins are generally small with steep fault-scarped margins. With continued back-arc spreading and accompanying volcanism, thick sequences of epiclastic sandy turbidites are deposited in a widening basin, which has smoother margins. Sandstone turbidites of the lower Connecting Point Group (Units C-1 to C-3), which show the evolution from a low-efficiency fan to one of improved efficiency, suggest deposition initially in a small, steep-sided basin that widened and had less precipitous slopes with time.

**Plate 14.** *A series of photographs that illustrate the thickening and coarsening upward of siliceous, thin- to medium-bedded turbidites of Unit C-6 at Salvage. 14a illustrates the thin planar-bedded nature of the most distal beds, which give way upward into thin-bedded, laminated and crosslaminated* $T_{bc}$ *turbidites (14b); proximal turbidites composed of graded, massive, medium-bedded sandstones (14c) occur at the top of the sequence.*

The basin maturity and the old age stages of the Carey and Sigurdsson (1984) model are dominated by widespread pelagic sedimentation with a diminishing epiclastic turbidite component as volcanism ended and spreading ceased. The importance of pelagic sediments in stage 3 of the Eastport basin fill may partly correspond to the maturity stage. However, the transition upward into a succession of classical turbidites deposited on an actively prograding deep-water fan (stage 4) suggests that: 1) maturing of the basin was interrupted by basin extension (see stage 3), 2) renewed uplift of a source terrane (not necessarily that which supplied the older Eastport basin fill) occurred and 3) this new cycle, perhaps involving similar sediments of the Connecting Point Group of Placentia Bay and parts of the Conception Group of the eastern Avalon Zone, culminated in the shallowing upward into deltaic and fluvial sediments as the basin accreted.

## SUMMARY

Volcaniclastic sediments of the Connecting Point Group and the underlying Love Cove Group possess the characteristics, composition and lithostratigraphic signature of volcanic arc basins. Pelagic and fine- to coarse-grained pyroclastic rocks, shale and related sediments, produced by sediment gravity flows having significant hydrothermal alteration, form the upper Love Cove Group and the base of the Connecting Point Group. The overlying basin fill consists of at least two packages of turbidites, separated stratigraphically by a mixtite unit. The lower package consists principally of an upward-coarsening sequence of turbidites that accumulated on a low-efficiency deep-sea fan. Such fans are typical of the deep-water volcaniclastic apron of volcanic arcs (Sigurdsson *et al.*, 1980; Carey and Sigurdsson, 1984) built up by the accumulation of large volumes of volcanic detritus. Thick, dominantly massive sand sequences are also commonly found in smaller basins where they are ponded by basin configuration and behind local barriers (Howell and Normark, 1982; Carey and Sigurdsson, 1984). The dominance of sand in the basin possibly reflects a narrow shelf between the arc and the basin, and steep gradients between source and depocentre. The steep slopes of volcanic edifices and the lack of vegetation on the Precambrian slopes facilitated the rapid production and movement of sand-sized material into the basin.

The presence of a well-developed levee-channel sequence in the upper part of the lower basin fill suggests that the sediment distribution capacity of the fan improved as the basin was infilled. This may reflect basin enlargement and gentler slopes. The lenticular nature of the channel-sand deposits in the fine, thin-bedded levee deposits suggests that channel avulsion was the principle mechanism by which sediment was distributed throughout the fan. However, the fining-upward sequences in some of the overbank sediment implies the channels must have also accreted laterally.

The mixtite that separates the two successions is interpreted as an olistostrome that formed when unconsolidated sediment of slope and basin collapsed and was transported farther into the basin. Its widespread distribution in the east of the area suggests that the mixtite probably was derived from the east. The locally southwestward-dipping imbrication of sediment rafts in the mixtite suggest, however, that in places the flow was moving northeastward immediately prior to deposition.

For the most part, the mass flow deposit involved only remobilization of slope and basin sediments. In the northeast, however, it contains scattered to common felsic volcanic and plutonic pebbles. The presence of these clasts may reflect the reworking of glacial deposits contemporaneous with the Gaskiers Formation tillite of the Conception Group (King, *in preparation*). Alternatively, it may indicate that proximal, possibly terrestrial volcanic deposits were remobilised and transported basinward by debris flows generated by the seismic activity that also triggered the submarine slides. The diabase clasts were derived from erosion of dykes that intruded the succession when the sediments were still unconsolidated.

These diabase dykes, which are common in the area northeast of Eastport, are also associated with a number of small mafic plutons. This suggests that the seismicity that may have triggered the production of the olistostrome coincided with basin extension by either basin pull-apart or by arc rifting.

The youngest basin fill above the mixtite is composed of well-developed sequences of turbidites. These rocks accumulated on deep-sea fans that were capable of efficient distribution of sediment over the submarine fan. Coarsening- and thickening-upward sequences indicate that the fans accreted by repeated progradation of suprafan lobes (Howell and Normark, 1982) on the smooth part of the fan. This upper sequence may be correlative with well-developed turbidites farther to the southwest, elsewhere in Bonavista Bay, and in the Placentia Bay area. This may indicate that the basin had enlarged with time and that its different configuration allowed the development of the classic deep-sea fan (cf. Walker, 1984).

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