

GEOLOGY OF THE ST. JOHN'S AREA, NEWFOUNDLAND

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ABSTRACT

Late Precambrian (Hadrynian) rocks of the St. John's peninsula form the most easterly land exposures of the Avalon Zone in the Appalachian Orogen. Fault-bounded pillow basalt and metatuff of the Harbour Main Group define the western boundary of the map area. Metatuff along Broad Cove River is conformably overlain by a thick marine sequence of volcanoclastic turbidites, submarine debris flows, and distal argillaceous turbidites of the Conception Group. Distinctive water-lain tuffs define the top of the Conception Group in the central part of the area and are conformably overlain by dark-gray shale, black shale containing discontinuous 'slump' beds of sandstone, and gray sandstone of the St. John's Group. The shale-sandstone sequence represents a shoaling of the Conception basin by a turbidite-fronted, southward-prograding delta. Subsequent fluvial deposition gave rise to green and red sandstones and conglomerates of the Signal Hill Group, in response to major uplift north of the present Avalon Peninsula.

The map area is divisible into six main structural zones. The rocks indicate a long history of volcanism, uplift, subsidence and progressive deformation. The effects of Acadian deformation appear dominant; the effects of the late Precambrian Avalonian Orogeny are enigmatic.

INTRODUCTION

Mapping of the bedrock geology and surficial deposits of 500 km² in and around the City of St. John's at 1:12,500 scale was undertaken during 1985, under contract with the Mineral Development Division of the Newfoundland Department of Mines and Energy. The contract area, shown in Figure 1, bounded by north latitudes 47° 27', and west longitudes 52° 37' and 52° 53' ('the map area'), comprises eleven Newfoundland Department of Forest Resources and Lands 1:12,500 map sheets (0252; 0253; 0255; 0256; 0259; 1251; 1254; north half of 0258 and 1257; south half of 0288 and 0289), and eight NTS 1:25,000 map sheets (IN/10L; IN/10b, a; IN/7f; 1N/7g; south half of IN/10G; east half of IN/10d and IN/7e).

Although the late Precambrian and Paleozoic rocks of the Avalon Peninsula have been studied for over 100 years, surprisingly, the St. John's peninsula has received sporadic attention and little is known about the volcanic and volcanoclastic stratigraphy, particularly of the Harbour Main and Conception groups, which underlie approximately two-thirds of the area. The only previously published large scale geological maps specifically of the St. John's peninsula are those of Rose (1952) at 1:253,440 scale and Hsu (1975) at 1:50,000 scale. An account of the previous geological work is given in King (1982).

The purpose of the present study is to document the distribution, origin and tectonic development of the late Precambrian lithofacies, and to provide a data base for subsequent hydrogeological and geotechnical investigations. This preliminary report outlines the main lithofacies. It is noteworthy that this survey represents the first, systematic,

detailed, regional mapping and division of the late Precambrian Harbour Main, Conception, St. John's, and Signal Hill groups in the map area since they were subdivided in the southern Avalon Peninsula by Williams and King (1979).

Field Program

The coastal geology was investigated in some detail and inland traverses were run from roads and rivers and along tracks, trails, and transmission lines. Quarries, trenches, water-sewer lines and various other excavations were examined and sampled. A helicopter was used to map the inaccessible coastal cliffs north of Portugal Cove and south of Torbay Point. A canoe was used on ponds and lakes. Color aerial photographs (1:12,500 scale) were particularly useful in determining structural trends. Initial maps were plotted at a scale of 1:12,500 and at 1:5,000 for the Torbay-Outer Cove area. In total, 1,600 site descriptions of bedrock and surficial deposits have been completed. There is a close correlation between bedrock lithology and dominant clast type in till, indicating that the till veneer is of local origin, commonly less than 2 km from the source.

Geological Setting

The St. John's peninsula is part of the Avalon Zone (Williams, 1976). Relatively unmetamorphosed late Precambrian volcanic rocks (Harbour Main Group), together with turbiditic siliceous siltstones and sandstones (Conception Group), basinal-deltaic shales and sandstones (St. John's Group), and molasse-like clastic sedimentary rocks (Signal Hill Group) are locally overlain by Cambrian and Ordovician marine-shelf sedimentary rocks, and define major elongate structural domes and basins, (e.g., Williams and

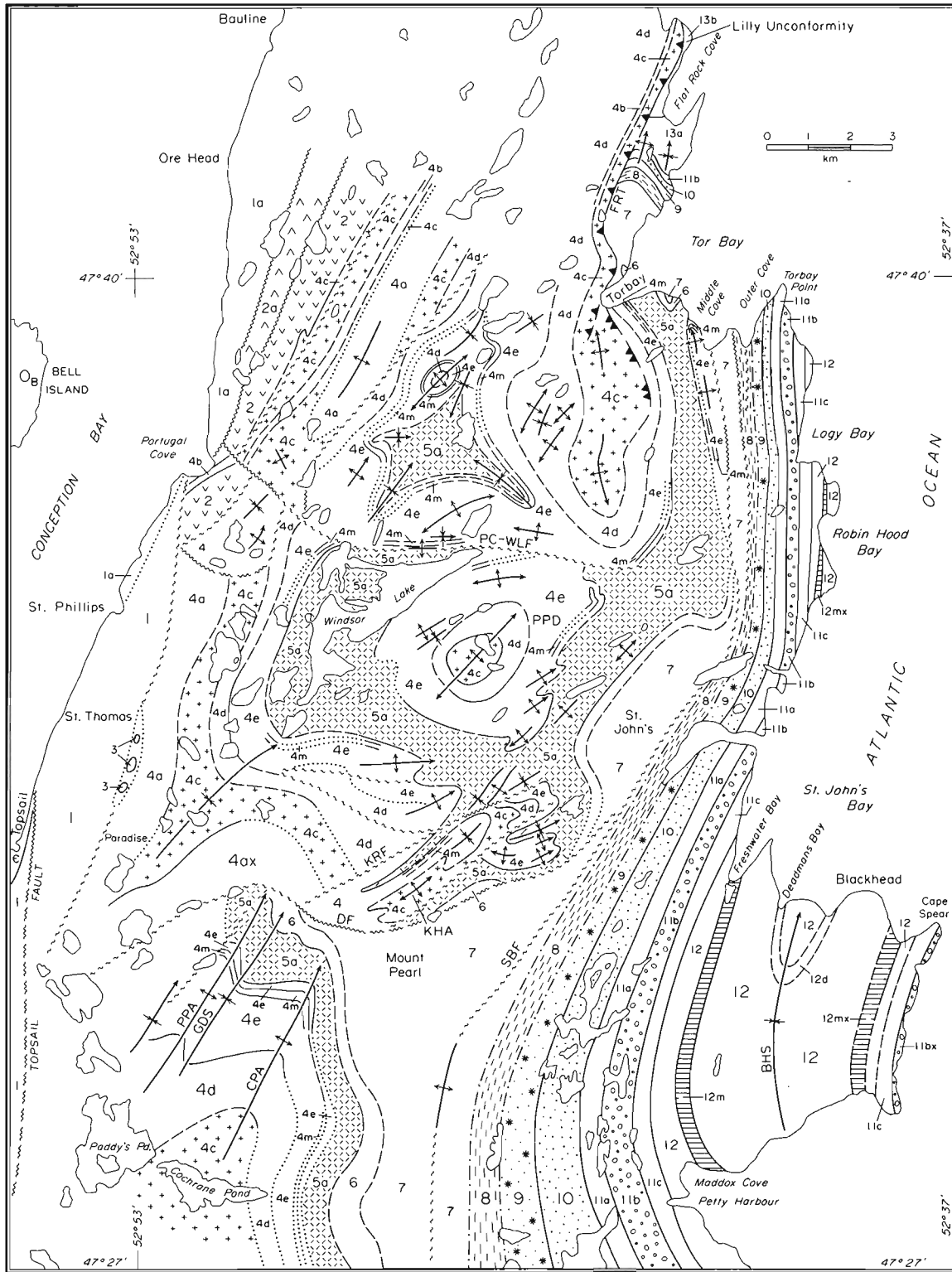


Figure 1: Geology of the St. John's area

LEGEND

ORDOVICIAN

OB BELL ISLAND GROUP: Sandstone, shale, ironstone

CAMBRIAN

C ADEYTON AND HARCOURT GROUPS: Shale

HADRYNIAN

SIGNAL HILL GROUP (Units 9 to 13); Latest Vendian to possibly early Paleozoic

- 12, 13 **Blackhead (12) and Flat Rock Cove (13) Formations:** red and gray sandstone, siltstone, mudstone, conglomerate and breccia.
- 12d *Deadmans Bay member*, green mudstone and sandstone.
- 12m *Maddox Cove member*, red mudstone and sandstone.
- 12mx Red sandstone and mudstone (possible equivalent of Maddox Cove Member).
- 13b *Piccos Brook Member*, locally derived breccia, red sandstone and mudstone.
- 13a *Knobby Hill Member*, gray conglomerate and sandstone.
- 11 **Cuckold Formation:** red conglomerate and sandstone.
- 11c *Petty Harbour member*, pebble conglomerate, fining upward into coarse grained sandstone.
- 11b *Logy Bay member*, cobble and pebble conglomerate containing exotic clasts.
- 11bx *Cape Spear member*, cobble conglomerate containing exotic clasts (probable equivalent of Logy Bay member).
- 11a *Cabot Tower member*, pebble conglomerate and coarse grained variegated sandstone.
- 10 **Quidi Vidi Formation:** red and green fine to medium grained sandstone, minor pebble conglomerate and mudstone.
- 9 **Gibbett Hill Formation:** thick bedded greenish-gray sandstone, locally greenish-gray siltstone, tuff and conglomerate, minor red sandstone and siltstone.

ST. JOHN'S GROUP (Units 6 to 8); Probably Vendian (670-590 Ma)

- 8 **Renews Head Formation:** thin lenticular bedded, dark rusty-gray sandstone and shale.
- 7 **Fermeuse Formation:** gray to black shale, contorted shale and sandstone, and thin bedded sandstone toward base.
- 6 **Trepassey Formation:** medium to thin bedded, graded, gray sandstone and shale, minor tuff.

CONCEPTION GROUP (Units 4 and 5); Probably Vendian (670-590 Ma)

- 5 **Mistaken Point Formation** *upper-part:* variegated tuffaceous shale and sandstone of Hibbs Hole member.
lower part: medium bedded, graded, tuffaceous, fossiliferous sandstone (gradational into Halfway Cove member).
- 5a *Hibbs Hole member*, medium to thick bedded, red, purple and green tuffaceous shale, siltstone and argillaceous sandstone (gradational into Trepassey Formation).
- 4 **Drook Formation:** greenish-gray siliceous sandstone, siltstone and tuff.
- 4e *Halfway Cove member*, laminated to medium bedded, greenish-gray and red, siliceous siltstone and tuffaceous sandstone; locally fossiliferous. Distinctive marker beds (map unit 4m) of red water-lain tuff and white vitric tuff near top of member.
- 4d *Mannings Hill member*, white to yellowish-green weathering, intercalated, thick siliceous sandstone, siltstone and graded tuffaceous sandstone.
- 4c *Torbay member*, streaky, laminated, coarse grained sandstone. Locally intercalated with Mannings Hill and Bauline Line members.
- 4b *Bauline Line member*, volcanogenic mixtite (possible northern facies of Gaskiers Formation tillite).
- 4a *Broad Cove River member*, greenish-gray chert and volcanoclastic sandstone.
- 4ax *Paradise member*, gray to green chert (stratigraphic position uncertain; possible equivalent of Broad Cove River member).

HARBOUR MAIN GROUP (Units 1 to 3); Possibly Late Riphean (1000-670 Ma)

- 3 **Dogberry Hill gabbro:** fine to coarse grained gabbro (age uncertain).
- 2 **Portugal Cove formation:** basaltic pillow lava.
- 2a *Blast Hole Ponds member*, metabasalt and tuff; minor granite.
- 1 **St. Phillips formation:** green metatuff, agglomerate, mafic lava and siliceous volcanoclastic sedimentary rocks, includes rhyolitic and gabbroic to diabasic intrusive rocks.
- 1a *Beachy Cove member*, strongly deformed and disrupted beds of siliceous volcanoclastic sedimentary rocks, basalt, rhyolite, tuff and agglomerate, includes rhyolitic and gabbroic to diabasic intrusive rocks.

King, 1979; King, 1980, 1982; O'Driscoll and King, 1985). The Precambrian rocks are intruded by granitoids of the 620 Ma Holyrood granite that are nonconformably overlain by Cambrian shales. The rocks were first deformed in the late Precambrian and subsequently regionally deformed and metamorphosed during the middle Paleozoic Acadian Orogeny. An account of the tectonic significance of the Avalon Zone of Newfoundland is given in O'Brien *et al.* (1983) and in King and O'Brien (*in press*).

GENERAL GEOLOGY

Formational Nomenclature

The Harbour Main Group (Rose, 1952) is provisionally divided into two new formations, St. Phillips and Portugal Cove, which are subdivided into the Beachy Cove and Blast Hole Ponds members respectively. Prominent gabbro plugs are here referred to as the Dogberry Hill gabbro. These represent the first formational divisions of this group.

The Conception Group nomenclature is essentially that of Williams and King (1979). The Drook Formation is provisionally subdivided here into six new members, Paradise, Broad Cove River, Bauline Line, Torbay, Mannings Hill, and Halfway Cove. During the field mapping, the Mistaken Point Formation was subdivided into a lower and upper part, the latter informally referred to as the Hibbs Hole member, a presumed correlative of the Hibbs Hole Formation (Hutchinson, 1953) at Conception Bay South.

The St. John's Group divisions are those of Williams and King (1979). These include, in ascending stratigraphic order, the Trepassey, Fermeuse and Renew's Head formations.

The Signal Hill Group nomenclature of Williams and King (1979) is retained with minor modification. The Cuckold Formation of the Signal Hill Group is subdivided into three new members, which in ascending order are Cabot Tower, Logy Bay and Petty Harbour; a fourth member, Cape Spear, is probably a correlative of the Logy Bay member. The Blackhead Formation is subdivided into five parts, two of which are the Maddox Cove and Deadman's Bay members; three remain unnamed.

Lithostratigraphy and Structure

The St. John's peninsula east of the Topsail Fault (Figure 1) is divisible into six main tectonostratigraphic zones, each with its own distinctive rock types and structural style. The principal distinguishing characteristics of the various formations and members are shown in the Legend for Figure 1; their vertical and lateral variations are summarized in Figures 2 and 3.

Zone 1. This zone (map Units 1, 1a, 2a, eastern Conception Bay), bounded by an eastern splay of the Topsail Fault, consists of highly deformed metatuffs (St. Phillips formation) which are associated with strongly deformed, siliceous, sedimentary rocks and mafic volcanic rocks (Beachy Cove member). Metamorphosed pillow basalt and tuff (Blast Hole Ponds member) to the north of Portugal Cove is a possible correlative of the St. Phillips formation. Associated granitoid rocks (Holyrood Intrusive Suite?) are boudinaged, but

younger plugs and dikes of gabbro (Dogberry Hill) and felsite occur along a fault marking the eastern boundary of the zone, and are for the most part undeformed.

Zone 2. This zone (map Units 2, 2a, Portugal Cove area) consists of fault-bounded blocks of massive and pillow basalt (Portugal Cove formation). Red argillite beds in the basalt exhibit open to tight folds. Stratigraphic top determinations in the argillite and pillows indicate much of the eastern margin of this zone, which is steeply dipping to the west, is overturned.

Zone 3. This zone (map Units 4a to 4e, Central St. John's peninsula) is in fault contact with Zones 1 and 2. It is characterized by siliceous volcanoclastic sedimentary rocks of the Drook Formation, the thickest and most extensive lithic unit in eastern Avalon Peninsula (Figure 2). Thick bedded greenish-gray chert and coarse grained volcanoclastic sandstone (map Unit 4a) are well exposed in Broad Cove River; the presence of rip-up clasts of tuff at the base suggests that this unit, the lowermost member of the Drook Formation, may disconformably overlie the St. Phillips Formation.

The cherts are conformably overlain by coarse grained arkosic sandstone (map Unit 4c) containing distinctive streaky laminae of siltstone and, locally, lenses and parallel laminae of silty sandstone, red tuff and orthoquartzite. This unit, provisionally named the Torbay member, is in part lithologically similar to coarse sandy facies of the Drook Formation associated with the Gaskiers Formation tillite at Cape English, southern Avalon Peninsula.

Along the Bauline Line, volcanogenic mixtite or diamictite (tillite?) is overlain by the Torbay member; elsewhere it is intercalated with thick units of streaky sandstone. The mixtite, provisionally named the Bauline Line member, may possibly represent a northern, coarse facies of the Gaskiers Formation.

The Torbay Member is overlain and locally intercalated with thick bedded siliceous sandstone, provisionally named the Mannings Hill member; excellent exposures occur at the Mannings Hill-Torbay Road intersection, opposite Torbay Post Office. Its white to yellowish-green weathering, gray to green and buff, siliceous sandstones, siltstones, argillites and cherts are the most widely recognized rock types that define the Drook Formation throughout the Avalon Peninsula (Williams and King, 1979).

The Mannings Hill member is conformably overlain by medium bedded siliceous sandstones and intercalated tuffs (map Unit 4e), provisionally named the Halfway Cove member (after a cove 'halfway' between Torbay and Middle Cove). A distinctive marker unit (Map Unit 4m) of red, water-lain tuff and white vitric tuff near the top of this member has been traced throughout the central part of the map area. Late Precambrian metazoan fossils were found immediately below and above the marker unit; the upper part of the Halfway Cove member is a possible correlative of the fossiliferous horizons identified in the type locality at Mistaken Point.

The various members of the Drook Formation are relatively competent rocks which form large scale domes and

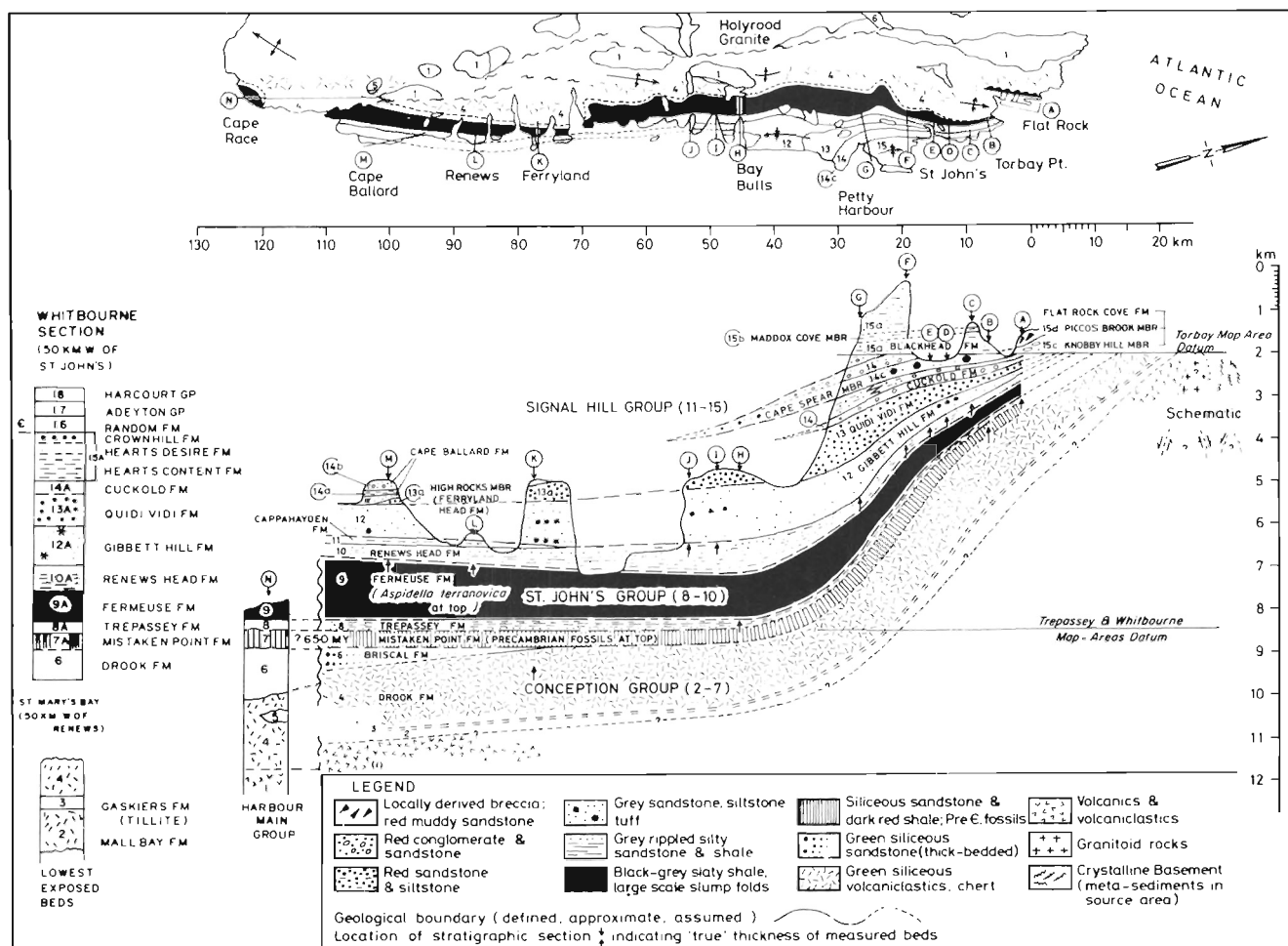


Figure 2: Stratigraphic profile of late Precambrian units, eastern Avalon Peninsula (modified after King, 1982).

basins, corresponding with areas of topographic high and low relief. Windsor Lake, for example, is within a complex structural basin.

Zone 4. This zone (map Units 5 and 6, central to eastern St. John's peninsula) lies conformably above Zone 3 and is easily recognized by conspicuous red and green tuffaceous siltstones and sandstones (map Unit 5a), which are correlatives of the Hibbs Hole member, now regarded as the upper part of the Mistaken Point Formation. Thin bedded, turbiditic, argillaceous sandstone (map Unit 6) of the Trepassey Formation defines the top of the zone. Both of these argillaceous units are highly susceptible to frost action and are therefore only exposed in the low ground between intervening domes, where they display an intricate pattern of interference folds.

Zone 5. This zone (map Units 7 and 8, eastern St. John's peninsula) is a coarsening upward sequence, stratigraphically above and to the east of Zone 4; it consists of tightly folded Fermeuse Formation black shale (map Unit 7) and Renew's Head Formation sandy shale (map Unit 8). Locally, where squeezed between competent units or where overthrust by competent units as in the Flat Rock thrust zone, Zone 5 pinches out tectonically.

Zone 6. This zone (map Units 9 to 13, eastern St. John's peninsula) is comprised of competent units of Gibbett Hill Formation green sandstone (Plate 1), Quidi Vidi Formation red sandstone (Plate 2), Cuckold Formation conglomerate (Plates 3 and 4; Figure 4), Blackhead Formation sandstone and mudstone (Plate 5) and Flat Rock Cove Formation conglomerate, sandstone and breccia. These units, although vertically persistent, show lateral variations in thickness, composition, and texture (Figure 2).

The Signal Hill Group rocks are the least deformed of the zones and throughout eastern Avalon Peninsula display broad, large scale, open folds, such as exemplified by the Blackhead Syncline.

STRUCTURAL GEOLOGY

Tectonic Setting

Two periods of deformation have been identified in eastern Avalon Peninsula: (1) an enigmatic Late Riphean to Vendian (Cadomian or Pan-African) orogenic episode, named the 'Avalonian' by Rodgers (1972) and first described as the 'Avalonian Orogeny' by Lilly (1966); (2) a major Siluro-Devonian (circa 395 Ma) disturbance, viz. the 'Acadian Orogeny'.

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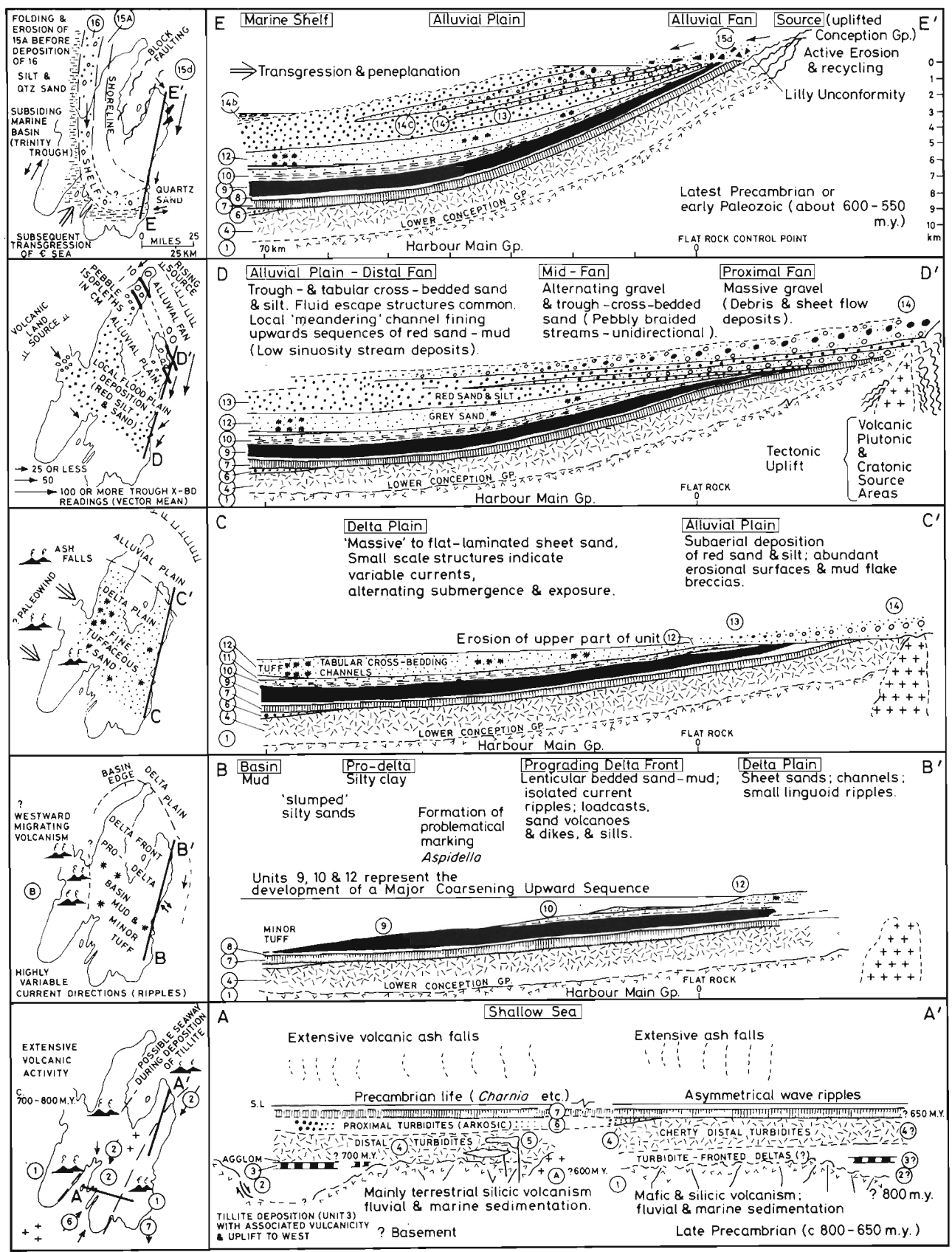


Figure 3: Late Precambrian and Early Paleozoic development of the Avalon Peninsula (Legend as for Figure 2).

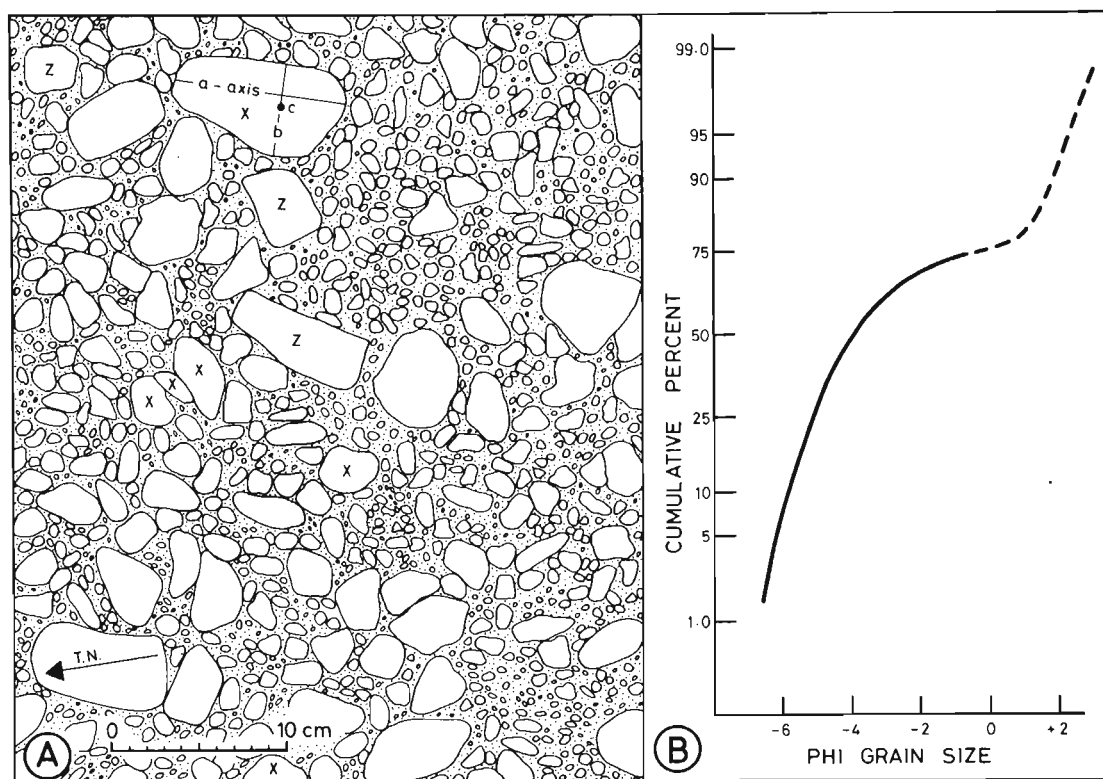


Figure 4: Clast and matrix variations in the Cape Spear Member, Cuckold Formation, Cape Spear.

- A. Plan view of conglomerate bedding surface showing clasts of rhyolite, tuff, quartz-sericite schist (x), and vein quartz (z) in a poorly sorted matrix. C-axis of largest clast is approximately 4 cm.
- B. Grain size cumulative curve for coarsest stratigraphic level in Cape Spear Member. Sample area $2\text{ m} \pm$ by 5 cm thick.

The effects of the late Precambrian Avalonian Orogeny are enigmatic. Pre-Tommotian unconformities in widespread localities throughout the Avalon Peninsula provide evidence of mainly Vendian folding, block-faulting, granitoid emplacement (620 Ma Holyrood Intrusive Suite) and general crustal instability, e.g., Lilly Unconformity, Figures 2 and 3. The present concentric arrangement of late Precambrian sedimentary rocks around a volcanic core in the eastern Avalon appears to be the result of Precambrian structural doming, since Lower Cambrian strata overstep the Conception Group to lie directly upon the Holyrood granite and Harbour Main Group volcanic rocks at Conception Bay (McCartney, 1967).

The effects of Acadian deformation and metamorphism in the Avalon Zone of Newfoundland are dominant but variable, reflecting the heterogeneity of the Acadian event. Metamorphism in eastern Avalon Peninsula occurred under prehnite-pumpellyite facies conditions (Papezik, 1973).

Major Tectonic Elements

The Precambrian rocks of the map area provide evidence of several phases of progressive deformation. The earliest phase is observable in the Mount Pearl - Kenmount Hill area. It is characterized by tight to isoclinal folds and associated strike-slip and thrust faults that have been refolded about

north-northwest to northeast-trending axes. The latest phase of deformation is assumed to relate to the Acadian Orogeny in which continued compression produced major open folds with steep axial surfaces and a coplanar cleavage. Examples are the gently northward plunging Paddy's Pond and Cochrane Pond anticlines and the Glendale and Blackhead synclines.

The Kenmount Hill anticlinorium provides evidence of multiple progressive deformations. It is a complex horst-like block of tightly folded Drook Formation strata; both early folds and associated faults within the block are refolded or warped about a major northerly trending axis. It is possible that the younger open folds resulted from warping and southward detachment of the block above a resistant basal unit, as may be provided by the Harbour Main Group volcanic rocks. Black shales of the St. John's Group exposed along Waterford River are separated from the block by the Donovans fault, and are warped around the southern end of the Kenmount Hill anticlinorium. A steeply dipping, north-northwest-trending slaty cleavage is well developed in the Fermeuse Formation in the Mount Pearl area and is possibly a product of the younger folding phase.

The South Brook Fault Zone extends from Outer Cove, through downtown St. John's, to the Goulds. It consists of a north-northeast-trending, 100 to 1000 m wide zone of tightly



Plate 1: *Low angle planar cross-stratification in Gibbett Hill Formation, Petty Harbour Road.*

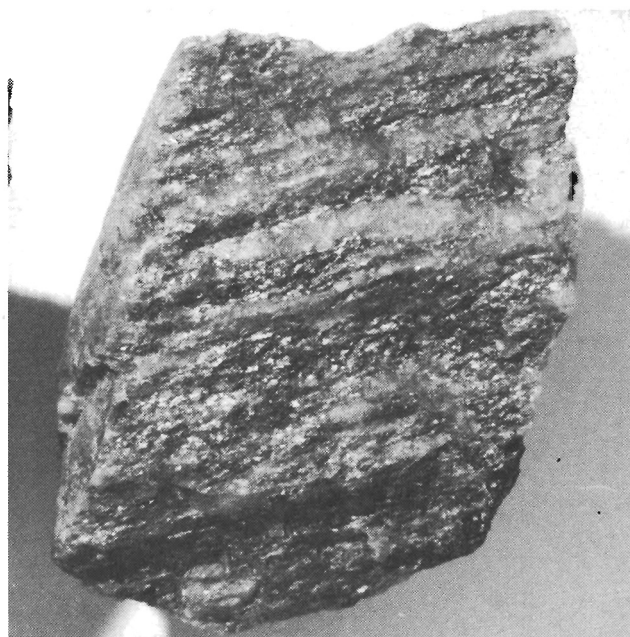


Plate 3: *Exotic clast of quartz-sericite schist, Logy Bay member, Cuckold Formation, Logy Bay; clast maximum diameter is 6 cm.*

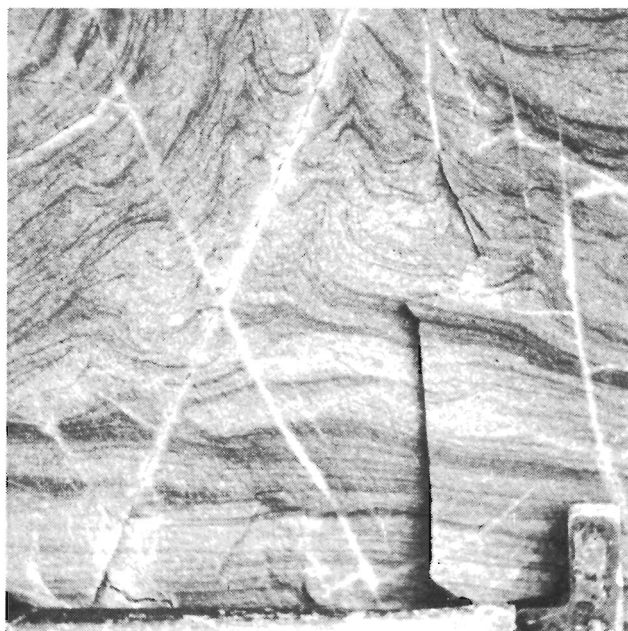


Plate 2: *Thixotropic deformation in Quidi Vidi Formation, Petty Harbour Road.*



Plate 4: *Alternating red sandstone and pebble conglomerate interpreted as mid-fan deposit; Petty Harbour member, Cuckold Formation, Cape Spear.*

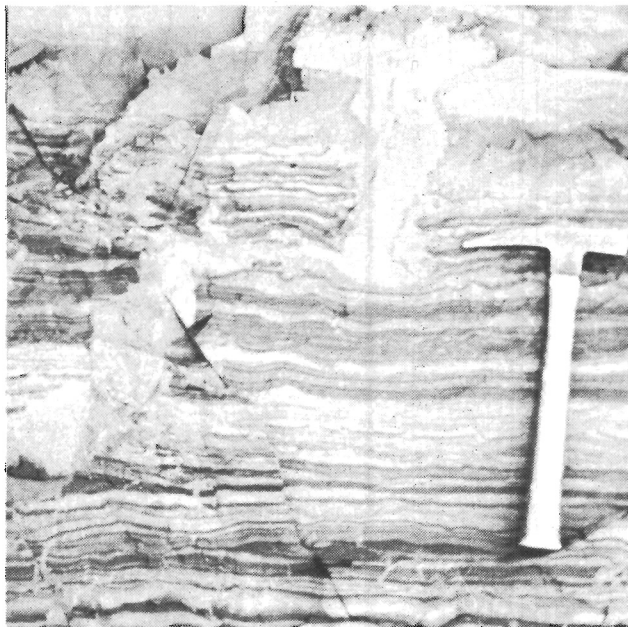


Plate 5: *Alternating thin red sandstone and mudstone, cut by sandstone dikes, Maddox Cove member, Blackhead Formation.*

folded, faulted and disrupted strata of the Fermeuse Formation. This zone resulted from intense compression and rupture of incompetent shales between relatively competent Conception Group sandstones within the domes to the west, and Signal Hill Group sandstones and conglomerates within the Blackhead Syncline to the east.

The Donovans Fault trends parallel to the Waterford River in the Donovans-Mount Pearl area and is interpreted to branch into two or more splay faults northeast of Mount Pearl. This fault is poorly exposed in the map area, except for local zones of intense fracturing, brecciation and massive quartz veining; its trace, however, at Donovans and along most of its length is marked by structural discontinuity, with the southern side downthrown.

The northeast-trending Kenmount Road fault is a narrow (up to 100 m wide) fault zone that defines the northern margin of the Kenmount Hill anticlinorium. Closely spaced and steeply northwest-dipping faults are exposed at several localities along its length. It is interpreted as a pivotal normal fault with the north side downthrown; slickensides and rock plucking along the fault surface indicate normal or down-dip movement.

The Portugal Cove - Windsor Lake Fault is a sinistral strike-slip fault with an oblique-slip component. Pillow basalts of the Portugal Cove formation are clearly offset by this fault in the vicinity of Portugal Cove.

Minor Tectonic Elements

Numerous joint sets and fracture zones are evident in virtually all rock units present in the map area. Joint systems are especially well developed in thick bedded sandstones and conglomerates of the Signal Hill Group.

Rhombohedral joints are characteristic of the Signal Hill Group and developed perpendicular to the stratification probably during early stages of folding. A fourth penetrative joint set (dip 15 to 35°N) in the Gibbett Hill Formation is filled with white quartz and minor pale-green prehnite, and traces of calcite, pyrite and pyrolusite. This set can be traced from Petty Harbour to Torbay Point. Some joint sets contain amethyst and copper minerals (O'Driscoll and King, 1985).

Open fracture zones, i.e., closely spaced, highly interconnected, discreet fractures, are characteristic of the siliceous Drook Formation. Iron (derived from weathered pyrite, hematite and magnetite) and manganese (pyrolusite) are common stains along fracture surfaces, indicating that fracture zones and, to a lesser extent, bedding surfaces are the primary conduits for groundwater movement in these otherwise well cemented, low matrix-porosity rocks.

Steeply dipping fractures and slaty cleavage are characteristic of the more argillaceous bedrock units such as the Mistaken Point, Trepassy, Fermeuse, and Renew's Head formations. The north-northwest trending slaty cleavage in the Fermeuse Formation in the Newtown - Mount Pearl area provides a conduit for groundwater movement and the migration of iron and manganese.

PALEOGEOGRAPHIC EVOLUTION

Schematic diagrams of the proposed evolution of the Avalon Peninsula, shown in Figure 3, are based on regional studies by King (1980, 1982, 1984) and are applicable to the Precambrian rock units in the map area. They reflect a long history of volcanic activity, uplift and subsidence.

Facies relationships indicate an early history of widespread marine turbidite and pelagic sedimentation (Conception Group) around an active volcanic archipelago (Harbour Main Group). The St. John's Group black shales record a shoaling of the marine basin, and then southward-prograding deposition of deltaic sands of the Gibbett Hill Formation (Plate 1). Local tuff beds in the Drook and Mistaken Point formations diminish upward in the St. John's Group and record waning volcanic activity. Tuff beds in the Gibbett Hill and overlying formations of the Signal Hill Group record intermittent deposition of volcanic ash. The presence of tuff and ash beds in the Signal Hill Group indicate contemporaneous sporadic volcanic activity, possibly related to the Bull Arm Formation volcanism which originated to the west of the Avalon Peninsula. It is noteworthy that mafic and felsic volcanic rocks which formed mainly in a subaerial environment between circa 630 and 570 Ma are widespread throughout the entire eastern margin of the Appalachians. This period was also a time of Precambrian, Avalonian tectonic movements. In eastern Newfoundland, a rising mountain front on the northern periphery of the present Avalon Peninsula gave rise to alluvial plain conditions, now represented by red sandstone (Quidi Vidi Formation), conglomerate (Cuckold Formation) and variegated sandstones and mudstones (Blackhead Formation), all of which constitute a molasse-like sequence resulting from tectonic upheaval (Plates 2 to 5).

Rock fragments and constituent detrital minerals indicate that the Signal Hill Group was derived largely from a source

area underlain by rocks of the Harbour Main and Conception groups and the Holyrood Intrusive Suite. However, the Gibbett Hill Formation also contains small amounts of detrital garnet and muscovite (Papezik, 1973); this, together with exotic clasts in the Logy Bay and Cape Spear members (Plate 3) and the northeasterly provenance of the Signal Hill Group sediments, may indicate the presence of crystalline basement rocks on the continental shelf to the northeast of the Avalon Peninsula.

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