STRATIGRAPHY, SEDIMENTOLOGY AND PALEOGEOGRAPHY OF MISSISSIPPIAN STRATA OF THE BAY ST. GEORGE SUBBASIN, WESTERN NEWFOUNDLAND

PART 1

IAN KNIGHT

STRATIGRAPHY, SEDIMENTOLOGY AND PALEOGEOGRAPHY OF MISSISSIPPIAN STRATA OF THE BAY ST. GEORGE SUBBASIN, WESTERN NEWFOUNDLAND

by

Ian Knight M.Sc.

Department of Earth Sciences

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ABSTRACT

The Bay St. George subbasin is one of two major depressions filled by Carboniferous sediments in insular Newfoundland. It is the northeast extension of the larger Maritimes Basin. It contains approximately 10 km of sediments ranging in age from Late Devonian to Late Carboniferous of which strata of the Anguille Group (Famennian - Tournaisian age) and the Codroy Group (Visean age) are described here. Both groups contain mostly nonmarine terrigenous clastic sediments with marine strata only within the Codroy Group.

The subbasin is believed to have formed as a pull-apart trough, rather than as a simple rift, adjacent to, and west of, the northeasterly trending Long Range fault, a major strike-slip structure that is part of the Hercynian Cabot Fault system in western Newfoundland. Dextral, strike-slip movements began in Middle or Late Devonian time and ended in Early Carboniferous (middle Visean) time. Three basin-fills, each approximately 3000 m thick, filled the pull-apart sequentially so that the oldest fill now occurs in the southwest and the youngest fill in the northeast. The first two basin-fills of Famennian and Tournasian age (Anguille Group), were deposited within an elongate, 30 km wide trough which initially formed between divergent faults near the southern margin of the Precambrian Steel Mountain anorthosite and which with time enlarged southwestward. The third basin-fill is made up of middle Visean strata (basal part of the Codroy Group). By this time, the subbasin had broadened to 60 km, and was irregular in shape, consisting of several subsiding

depressions separated by fault-bounded archs. Wrench movements ceased in middle Visean time and the subbasin was subsequently influenced by block faulting when sediments of the upper part of the Codroy Group were deposited.

The Anguille Group comprises Famennian redbeds (Kennels Brook Formation), and Tournaisian deepwater lacustrine black shales and mudstones, and turbidite and deltaic sandstones (Snakes Bight Formation), gray, fluvial-deltaic sandstones and shales (Friars Cove Formation), and red braided stream sediments (Spout Falls Formation). Gray conglomerates of the Fischells conglomerate member of the Spout Falls Formation formed a local alluvial fan on the northwestern margin of the subbasin.

The Codroy Group of middle to late Visean age consists of marine and nonmarine rocks that appear to overlie conformably the Anguille Group. The basal Ship Cove Formation is a thin, subtidal to intertidal, laminated limestone (Windsor subzone A). Subsequent marine sedimentation includes sulphate and chloride evaporites that accumulated in sabkhas and shallow salinas (Codroy Road Formation and lower Jeffrey's Village Member of the Robinsons River Formation - Windsor subzones A and lower B). Associated carbonates and fine grained, gray to red siliciclastic rocks of the Codroy Road Formation and Jeffrey's Village Member formed in shallow seas, in lagoons, on shorelines and rarely as bioherms. Some nonmarine redbeds are intercalated with the basal marine deposits, and increasingly dominate the upper part of the Jeffrey's Village Member and the overlying

Highlands Member of the Robinsons River Formation (Windsor subzones B and C). These redbeds were laid down on playa flats, on coastal and alluvial plains and on alluvial fans. Younger strata of the Codroy Group are confined to the southwest of the subbasin. Flood plain and alluvial fan were deposited there together with minor lacustrine and shallow marine rocks of the Mollichignick and Overfall Brook Members of the Robinsons River Formation and deltaic rocks of the Woody Cape Formation (Windsor subzones D and E).

Detritus for the groups was principally derived from uplifted Lower Paleozoic crystalline and volcanic terranes southeast and northeast of the subbasin. Lower Paleozoic platformal carbonates and quartzites and Taconic allochthonous ophiolite and flysch sequences were an important local source area for the Anguille Group northwest of the subbasin.

Evaporites and calcretes suggest that the Carboniferous climate was dominantly semiarid. Aridity was most intense during the middle Visean but humidity increased during the late Visean.

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CHAPTER 1

INTRODUCTION

Rocks of Carboniferous age occur in several areas of Newfoundland (Figures 1 and 2); the best known are those in the Deer Lake and St. George's Bay areas. The Carboniferous rocks of the St. George's Bay area form the northeastern corner of the Maritimes Basin (Williams, 1974), a much larger Carboniferous basin that underlies the Gulf of St. Lawrence and adjacent land areas (Figures 1 and 2). The part of the basin in southwestern Newfoundland is termed the Bay St. George subbasin and it is the subject of this report. Onshore the subbasin is developed in a zone 22 km wide between St. George's Bay and the Long Range Mountains, extending 125 km from the coast near the Codroy Valley, northeast to the vicinity of Stephenville. Rocks of Carboniferous age that belong to the Bay St. George subbasin extend offshore beneath St. George's Bay (Figure 2).

Geographical Setting

Three distinct topographic areas occur in the Bay St. George subbasin, namely, the St. George's Bay lowlands, the Anguille Mountains and Bald Mountain, and the Codroy lowlands (Figure 3).

The St. George's Bay lowlands consist of a gently rolling coastal plain, 60 m in elevation, which rises gradually to 225 to 300 m as it is traced inland towards the Long Range Mountains. The latter mountains form a dissected 450 m plateau, rising abruptly from the lowlands along a pronounced scarp. The lowlands are fashioned generally from easily weathered sedimentary rocks of the Codroy and

Barachois Groups. However, more resistant strata in the vicinity of Brow Pond and Mt. Howley form a steep upland plateau, 300 to 375 m high. Thick glacial drift as well as outwash and marine deposits (Brookes, 1969, 1977b; Vanderveer, 1975) cover much of the area and have been incised up to 90 m by rivers which cross the lowland, northwestward from the Long Range Mountains.

The Anguille Mountains and Bald Mountain are composed of more resistant Anguille Group strata and form an upland, averaging 525 m in elevation with steep flanks, generally reflecting the structural dip of underlying rocks. Streams, which are generally short with a steep gradient, radiate out from the mountains, whereas some long streams run parallel to the structural trends. The mountains were only locally affected by glaciation (Twenhofel and MacClintock, 1940; Brookes, 1977a).

The Codroy lowlands are a southwesterly trending, funnel-shaped, geomorphic feature beginning near South Branch and opening out to the southwest; they are drained by the Grand Codroy and Little Codroy Rivers. The lowlands are a preglacial feature, modified by Wisconsin ice movements (Brookes, 1977a) and scoured in Codroy and Barachois Group strata. They lie between the Anguille Mountains and the southern end of the Long Range Mountains.

The coastline throughout the area is lined by cliffs. Sandy beaches are rare except locally in the Codroy lowlands and more extensively along St. George's Bay. The area is generally covered with spruce forests, low-lying tuckamore spruce, open heaths and large boglands. A cool temperate climate with moderate precipitation and generally heavy snowfall is characteristic of the area. Summers had little rainfall during the period of the study.

Access to the area is provided by the Trans Canada Highway from which secondary roads branch to the many coastal settlements. Woods roads, power lines, the main Newfoundland railway line, and rivers and streams provide further access into the area. Much of the coast in the St. George's Bay and Codroy lowlands is accessible by road and foot but the coastal exposures in the Anguille Mountains generally cannot be reached without the use of a small boat.

Regional Geological Setting

Carboniferous rocks are extensive throughout the Atlantic Provinces (Poole, 1967; Belt, 1968a and b; Hacquebard, 1972) and offshore areas that surround Newfoundland (Sheridan and Drake, 1968; Watts, 1972; Williams, 1974; Haworth and Sanford, 1976; Haworth et al., 1976; Jansa and Wade, 1975) (Figure 1). A Carboniferous basin, the Maritimes Basin, has been delineated by onshore mapping and extensive geophysical surveys of offshore areas. It underlies large parts of Nova Scotia, New Brunswick, Cape Breton and Prince Edward Island and extends beneath the Gulf of St. Lawrence to outcrop onshore in southwestern Newfoundland.

The name, Maritimes Basin (Williams, 1974), is preferred here to Fundy Basin (Belt 1965, 1968a and b, 1969; Kelley, 1967b), Fundy geosyncline (Poole, 1967), Fundy epieugeosyncline (Hacquebard, 1972; Howie and Barss, 1975a and b) or St. Lawrence basin (Geldsetzer, 1979). The term Maritimes Basin is used strictly in the geographical sense to define a depositional basin in which all salient features of the Carboniferous of the area can be grouped and includes no reference to the presence or absence of deformation.

Three structural elements occur in the Maritimes Basin: platforms, subbasins and arches or ridges. The platforms (Figure 2) overlie older Acadian basement and are composed of relatively undeformed sedimentary rocks up to 2000 m thick. They include the New Brunswick platform and the Nova Scotia platform. The Newfoundland platform, which Belt (1969) and Hacquebard (1972) proposed as occurring in the central parts of the island, does not strictly conform to the above definition of a Carboniferous platform. Central Newfoundland shows no evidence of having been covered by a sedimentary blanket; instead, during the Carboniferous, it was a major upland from which large quantities of detritus were shed into the adjacent basins. Some fault-controlled Carboniferous deposits were, however, laid down in very localized, landlocked valleys, e.g. Red Indian Lake (Kean, 1978).

A complex of subbasins containing up to 9 km of Carboniferous rocks (Figure 2) occurs in the centre and along the southeastern side of the Maritimes Basin. They have been delineated by mapping, geophysical surveys and drilling, and include the Cumberland basin, Moncton basin and East and West Magdalen basins (Belt, 1968b; Watts, 1972). The Bay St. George subbasin projects northeastwards from the

East Magdalen basin (Haworth, 1975a and b) from which it is separated by a narrow arch (Howie and Barss, 1975a). Hobson and Overton (1973) and Spector (1969) suggested that 6 km of sedimentary rocks occur in the Bay St George subbasin, however the present work suggests that up to 10 km of sediment was originally deposited. A small, unnamed, north trending Carboniferous subbasin formed along the western edge of the Humber Arm Allochthon just west and north of the Port au Port Peninsula (Shearer, 1973; Haworth and Sanford, 1976).

The subbasins are separated by ridges or arches (Figure 2). These topographic highs are composed of exposed basement rocks such as the Cape Breton Highland Massif and Cobequid Arch-Antigonish Massif (Belt, 1968b), or are hidden by a thinned Carboniferous sedimentary cover up to 4 km thick, for example, the East Magdalen Ridge (Watts, 1972; Mayhew, 1974). A major ridge, the Cape Breton-Newfoundland Ridge (Watts, 1972; Mayhew, 1974), extends across Cabot Strait from the Cape Breton Highland Massif to the Long Range Mountains of southwestern Newfoundland. This ridge forms part of the southeastern margin of the Maritimes Basin, separating it from the Sydney Basin (Howie and Barss, 1975a and b; Jansa and Wade, 1975) and other depocenters on the Grand Banks and the continental shelf of Atlantic Canada. Howie and Barss (1975a) believe, however, that a thin veneer of Carboniferous rocks was probably deposited over the Cape Breton-Newfoundland ridge. The Deer Lake and White Bay Carboniferous basins, although occurring only 50 km northeast of the Bay St George subbasin, are believed to have been separated by an upland that supplied detritus to both basins.

The Maritimes Basin is essentially a successor basin formed after the completion of the Acadian deformation of the Appalachian fold belt (Poole, 1967; Belt, 1968b; Hacquebard, 1972; Williams et al., 1974). Uplift of the fold belt probably started during or soon after the Early Devonian and molasse sedimentation became widespread by the Late Devonian in a taphrogenic zone (Poole, 1976). The northern margin of the Maritimes Basin probably lies along the southern edge of the Laurentian platform northwest of the Appalachian Orogen. It coincides with the northern limit of Acadian deformation (Haworth, 1975a and b), which generally trends westward from the Port au Port Peninsula to the south of Anticosti Island.

The Maritimes Basin was filled mainly by fluviatile sediment throughout its history, beginning in Late Devonian time and continuing to the Early Permian (Hacquebard, 1972; Geldsetzer, 1978). Lacustrine sedimentary rocks (Belt, 1965, 1968a) also occur, and one major marine incursion is recorded in Upper Mississippian strata (Bell, 1929; Mamet, 1970). Several rock groups are defined in the Maritimes Basin, namely, in ascending order, the Horton, Windsor, Canso/Riversdale, Cumberland and Pictou Groups (Hacquebard, 1972). In southwestern Newfoundland three groups have been defined, namely, the Anguille, Codroy and Barachois Groups. They are broadly both lithological and time equivalents of the Horton, Windsor, Canso/ Riversdale and, possibly, Cumberland Groups of Nova Scotia (Table 1). The main marine incursion is recorded in the Windsor-Codroy Groups. It corresponds to a late Visean marine transgression which occurred throughout North Africa and Europe (Schenk, 1971; Dillon and Sougy, 1974). A major hiatus in sedimentation from late Tournaisian until middle Visean time has been postulated to have occurred in the Maritimes Basin before deposition of the marine sequence (Mamet, 1970; Geldsetzer, 1977, 1978; Utting, 1980). This is disputed, however, by Belt (1968a and b), Schenk (1975a) and Howie and Barss (1975a), who found no sedimentary break in many places. Recent spore studies reveal a mixed Horton-Windsor assemblage in basal Windsor units which Utting (1980) hinted may support the view that the two groups are conformable. Rock-stratigraphic relationships in the Bay St. George subbasin (Knight, 1983) support the notion of a conformable boundary. Here, as elsewhere in Maritime Canada, no biostratigraphic evidence is available to augment the lithostratigraphic relationships.

In general, volcanic rocks are rare in the Maritimes Basin. They do, however, occur in the Mississippian and Pennsylvanian of New Brunswick and the Magdalen Islands, in Hortonian strata of the Fisset Brook Formation on Cape Breton, and in Upper Devonian rocks near Antigonish (Keppie et al., 1978). The Fisset Brook Formation abuts the Cape Breton Highland Massif (Figure 2) and is considered to underlie and to be older than strata of the Horton Group. It consists of intermediate to felsic volcanic rocks intercalated with Horton-type sedimentary rocks (Kelley and Mackasey, 1965). They compare closely in tectonic position and lithology to the Windsor Point Group (Brown, 1977; Chorlton, 1979; Chorlton and Dingwell, 1981) which lies along the Cape Ray Fault in southwestern Newfoundland. However, sedimentary rocks from the Windsor Point Group (Chorlton, 1979; Chorlton and Dingwell, 1981; Cooper, 1954) contain plant fossils which have been dated as Early Devonian (Dorf and Cooper, 1943; Chorlton, personal communication, 1980) and hence are clearly older than the Fisset Brook Formation of Cape Breton.

The rocks of the Maritimes Basin were deformed in the Late Carboniferous during the Maritime disturbance (Poole, 1967, 1976; Schenk, 1971, 1978). The deformation was most intense along a narrow zone which extends through the Deer Lake Basin (Hyde, 1978, 1979a, 1979b; Hyde and Ware, 1980) to the Bay St. George subbasin (Knight, 1983), and across the Cabot Strait to the western side of Cape Breton. It then passes westwards through northern Nova Scotia and southwestwards into southern New Brunswick. This structural zone is called the Fundy 'basin' by Belt (1968a and b). Deformation in the zone produced **en echelon** fold axes, recumbent folds, cleavage, steep to inverted bedding and high angle, marginal and in-basin faults. For these and other reasons, Belt (1968b, 1969) related the deformation to oblique-slip movements along the basin margin faults. Tilted Lower Carboniferous rock sequences are overlain unconformably by younger Carboniferous strata in the Deer Lake Basin (Hyde and Ware, 1981), in Northern Cape Breton (Currie, 1977) and at Cape George, northern Nova Scotia (Keppie et al., 1978). Such occurrences testify to local uplift and deformation adjacent to faults during various time intervals in the mobile zone of the Maritimes Basin.

Paleo-reconstructions of Laurussia and Gondwanaland (see LeFort and van der Voo, 1981) at the end of the Carboniferous, and detailed studies of Devonian and Carboniferous rock facies and deformational events in North America, North Africa and Europe (Schenk, 1971; McKerrow and Zeigler, 1972; Rast and Grant, 1973; Dewey, 1974; Dewey and Kidd, 1974) indicate that the Late Carboniferous-Early Permian Variscan/Hercynian orogeny must have affected the Maritimes area. The deformation is postulated to have resulted from collision of the North African plate with the North American plate. In Atlantic Canada it produced the Maritime disturbance (Dewey and Kidd, 1974) which was confined to the mobile zone of the Maritimes Basin. Zones of deformation coincide with areas of thickest Carboniferous deposition. More recently, paleomagnetic and paleotectonic analysis of Devonian and Carboniferous strata on a global scale suggest that both sedimentation and deformation were controlled by large-scale, wrench fault movements (Schenk, 1978; Kent and Opdyke, 1978, 1979; van der Voo et al., 1979; Irving, 1979; Bradley, 1982).

Devonian and Carboniferous paleomagnetic poles for the Maritimes Basin differ from those of cratonic North America (Kent and Opdyke, 1978, 1979; Irving, 1979). This has led these authors to suggest major left-lateral displacement by 1500 km of an exotic terrane called Acadia (Kent and Opdyke, 1979) or Appalachia (Irving, 1979). The movements, which are postulated to have continued from the Devonian to the Permian, would clearly have influenced the siting and/or migration of basins as well as their infill and their deformation throughout the Middle and Late Paleozoic.

In contrast, the formation of the Variscan fold belt has recently been reinterpreted as the product of a right-lateral megashear between a sutured American-European plate and an African plate (Arthaud and Matte, 1977). Maritime Canada, in its position close to the southern margin of the American-European plate, is shown to be part of this system (Figure 9, page 1317, Arthaud and Matte, 1977). Bradley (1982) has recently interpreted the formation and deformation of the Maritimes Basin as the products of dominantly right-lateral strike slip upon major regional faults.

Stratigraphic, sedimentologic and structural relationships within the Carboniferous rocks in the Bay St. George subbasin all suggest its evolution was largely influenced by right-lateral wrench tectonics and by block faulting (Knight, 1983). Preliminary petrographic studies also indicate that the basin evolved adjacent to the geologic terranes that presently surround it.

Local Geological Setting

The north-easterly trending Bay St. George subbasin is located at the junction between the southern margin of the St. Lawrence platform and the Acadian-deformed rocks of central Newfoundland. It is closely associated both geographically and depositionally with a major fault zone that includes the Cabot Fault of Wilson (1962) to the north of the subbasin and the Long Range fault (Bell, 1948; Riley, 1962), which forms the southeastern margin of the subbasin itself.

Two distinct basement terranes occur to the north and southeast of the Bay St. George subbasin. To the north, the basement is composed of rocks which together form the Humber tectonostratigraphic zone of the

Newfoundland Appalachians (Williams, 1978). The rock types (Williams et al., 1972, 1974) include (1) Precambrian gneisses, probable Grenvillian granites and anorthosites and Cambrian diabase dikes; (2) Cambro-Ordovician clastic and carbonate rocks; (3) transported sedimentary, volcanic and ophiolitic rocks of the Humber Arm Allochthon; (4) greenschist-grade metasedimentary rocks similar to the Fleur de Lys Group; and (5) late Silurian-Devonian redbeds of the Clam Bank Formation (Rodgers, 1965; O'Brien, 1975).

To the southeast, the basement formed a major upland area in central Newfoundland. This upland was surrounded by Devonian and Carboniferous molasse and is now underlain by rocks of Precambrian? to Devonian age. It includes dismembered ophiolites, metamorphic, volcanic, sedimentary and intrusive rocks of the Dunnage and Gander Zones of Williams (1978). The southern part of the Long Range Mountains which lie adjacent to the Bay St. George subbasin were included in the Humber Zone by Williams (1978). New evidence (Chorlton and Dingwell, 1981; Chorlton, in Chorlton and Knight, 1983) indicates, however, that a large part of this area is underlain by Lower Palaeozoic oceanic crust and should be assigned to Williams's Dunnage Zone.

The geologic terrane southeast of the Long Range fault is traversed by the Cape Ray fault. The latter separates deformed Lower Paleozoic oceanic crust (Long Range tonalitic gneisses and rocks of the Long Range ultramafic-mafic complex of Brown, 1976) from a thick succession of Ordovician metasedimentary and island arc volcanic-sedimentary rocks that overlie amphibolitized oceanic crust (Bay du Nord and La Poile Groups) (Chorlton, in Chorlton and Knight, 1983). Granitoids are present on both sides of the Cape Ray fault. The Devonian Windsor Point Group is composed of a strongly bimodal, subaerial volcanic rock suite with interbedded volcaniclastic and sedimentary rocks and occurs at several localities along the trace of the fault.

Ordovician to Silurian, felsic to mafic lavas, pyroclastics and related volcanogenic sediments of the Victoria Lake and Buchans Groups (Kean, 1977, 1978) occur further north in the central Newfoundland upland. These grade southwards into a belt of paragneiss and migmatites (Jayasinghe, 1979). Redbeds and intercalated, subaerial, mafic to felsic volcanic rocks of the Botwood and Springdale Groups (Williams et al., 1972; Kean, 1979) are also found. Granitoid rocks intrude these groups and include the Topsails Igneous Complex (Taylor et al., 1980) and the informal Lloyds River intrusive suite (Kean, in preparation). Intrusive rock types include granites, granodiorites, quartz monzonites, quartz diorites, alkalic granites and gabbros.

Previous Work

Carboniferous rocks of southwestern Newfoundland have been studied intermittently for over a century since they were first identified by Jukes (1843) and Alexander Murray (1873; Murray and Howley, 1880).

Description and subdivision of the Carboniferous rocks began in 1873 when Murray identified two major subdivisions, the Mississippian

Windsor marine series and the overlying, possibly Pennsylvanian, coal measures. He noted that five lithological sequences comprised these subdivisions. These five sequences correspond closely to more recently determined stratigraphic subdivisions (Table 1). Murray also measured a number of sections along Fischells Brook, in the coalfield of the St. George's Bay lowlands, and along the coast of the Codroy lowlands.

A three-fold subdivision of the Carboniferous into the Anguille, Codroy and Barachois Series was proposed by Hayes and Johnson (1938) and followed by Bell (1948) (Table 1). Both these investigations described the lithologies and fossils of the subbasin. The faunas of the Codroy Series, Bell (1948) noted, were molluscan-dominated, and the fossils were small and of restricted diversity in comparison to those of the Windsor Group of Nova Scotia. Nevertheless, they enabled him to identify the presence of the Windsor marine fossiliferous subzones of Nova Scotia (Bell, 1929) in the Codroy Series. The shelly faunas in the subbasin thus have a close affinity to those found in northwestern European Visean rocks (Bell, 1929) rather than to the faunas of Mississippian sedimentary rocks of continental North America. Bell (1948) also named many of the limestone units in the area and introduced names for some of the Codroy coastal sequences; for example, the Searston beds (Table 1). He also interpreted the depositional environments of the series and described the subbasin in a regional Maritime setting. The three series were redefined as groups by Baird and Cote (1964) and Cote (1964), who proposed a subdivision of the Anguille Group into three formations (Table 1) and divided the Codroy Group into lower and upper subdivisions. They described lithologies briefly and showed that rocks of the Anguille Group were nonmarine and included river-lain and lacustrine deposits.

Utting (1966) studied the fauna and microflora of the Searston beds and other strata in the Codroy Valley. He identified flora of Namurian A age in the Searston beds, Westphalian A age in coal beds near South Branch, and a marine fauna in other strata of Windsor age. The ages of coals in the subbasin were dated by Hacquebard et al. (1961) using miospores. They suggested that the coals of the Codroy Valley are slightly older than coal measures in the St. George's coalfield although both are Westphalian A in age.

Foraminifera were identified from the Crabbes limestone, St. George's Bay, by Mamet (1968), who suggested a Windsor subzone C age for the important marker bed. The foraminifera were shown to have the greatest affinity to those of the Arctic realm rather than Tethyan or North American faunas. He reported that " most species common to Newfoundland and western Europe are found in northern Siberia ,Alaska, Yukon and the Canadian Arctic Islands ". He came to a similiar conclusion in a broader study of the foraminifera of the Windsor Group of Nova Scotia (Mamet, 1970).

Since this study started in 1974, paleontological studies of shelly faunas (McGlynn, personal communication, 1979) and conodonts (von Bitter, 1975; von Bitter and Plint-Geberl, 1978, 1979, 1982) have provided additional biostratigraphic information for the Codroy Group. Shelly faunas collected by McGlynn from limestones and shales of the

Codroy Group generally substantiate the subzone determinations of Bell (1948). McGlynn has expanded the known faunal list and renamed many of Bell's species in accordance with recent fossil nomenclature for the Windsor Group (Moore and Ryan, 1976). Conodonts extracted from the many marine units of the Codroy Group have been subdivided into four faunal assemblage zones (von Bitter and Plint-Geberl, 1982) and correlated with the macrofaunal subzones of the Windsor Group.

Comparison of the Newfoundland Carboniferous with similar strata in the Maritime provinces was made in the earliest work by Murray (1873) and continued in later studies (Hayes and Johnson, 1938; Bell, 1948; Baird and Cote, 1964; Cote, 1964; Knight, 1983). The main conclusions were that the Anguille and Codroy Groups compared closely with the Horton and Windsor Groups of Nova Scotia.

Stratigraphy, sedimentology and tectonic setting were investigated later by Belt (unpublished report, 1966). He described lithofacies (Belt et al., 1967; Belt, 1968a), patterns of sedimentation (Belt, 1968a), and tectonic framework for the Carboniferous rocks in eastern Canada (Belt, 1968b) and also provided the basis for comparison of the Newfoundland Carboniferous with that of the northern British Isles (Belt et al., 1967; Belt, 1969). He showed a consistent pattern of sedimentation in both Newfoundland and the rest of the Maritimes. Alluvial fans formed adjacent to the subbasin margins and passed basinward into alluvial plain fluviatile sequences which in turn passed into lacustrine rocks in the center of the subbasin. This pattern is generally confirmed by recent lithofacies and stratigraphic studies in the subbasin by Knight (1983).

Maps of the Bay St. George subbasin have been produced by several workers at a number of different scales. The earliest maps are those of Hayes and Johnson (1938) which show the broad distribution of the three rock series with more detailed maps of the Codroy area and the St. George's coalfield. Bell (1948) produced small detailed maps of the Codroy area and the coast of St. George's Bay. Part of the Anguille Mountains was mapped by Baird and Cote (1964). The whole area was covered sparingly in 1:250,000 maps by Riley (1962) and Gillis (1972). Recently, Knight (1983) compiled the geology of the subbasin in a map of 1:125,000 scale. A geological map of the St. George's Bay lowlands was prepared by Verrall (1954b) during a gravity survey. Structural studies have concentrated on marginal and intrabasinal faults and associated folds (Phair, 1949; Belt, 1968b, 1969; Belt et al., 1969; Webb, 1969: Knight, 1983) and all suggest that the Long Range fault possessed a dextral strike-slip component of motion.

The presence of such potentially economic commodities as coal, industrial minerals, evaporites and base metals has lead to some important economic assessment studies in the area. After the discovery of coal by Jukes and Murray (Howley, 1897), much effort was expended on further discovery and description of the coal measures (Howley, 1897, 1913; Baker, 1927; Bryan, 1938; Summers, 1948; Hayes, 1949). The description and evaluation of the widespread gypsum deposits of the area (Baird, 1951, 1954, 1959; McKillop, 1953a and b, 1959) led to outlining reserves of about 300 million tonnes and establishment of the currently operative Flat Bay gypsum mine in 1951. Fleming (1974) outlined the salt potential of the basin. Base metals and industrial minerals were briefly described by Johnson (1954), Riley (1962), McArthur (1973) and Fleming and McArthur (1976). Many of these reports also provide important geological information, much of which is summarised and expanded by Knight (1983).

History of the Present Investigation

The rocks of the subbasin were systematically mapped on a 1:50,000 scale by geologists of the Newfoundland Department of Mines during the summers of 1974 and 1975 following a reconnaissance study of the rock types, stratigraphy and mineralization in 1973 (Stevens and Knight, 1974). For mapping, the subbasin was divided into two areas. The southwestern part including the Anguille Mountains, Bald Mountain and the Codroy lowlands, was mapped by Knight (1975, 1976). The St. George's Bay lowlands were mapped by Fong (1974, 1976a and b; Fong and Douglas, 1975). Compilation and synthesis of the data collected became the responsibility of Knight after 1976. Since then, a number of short visits have been made to the area by the author in order to assist this compilation. The discovery of base metal mineralization in the area (Stevens and Knight,1974), the delineation of a major Pb-Zn deposit in the Carboniferous rocks at Gays River, Nova Scotia, the presence of evaporites including gypsum and salt and the existence of only reconnaisance mapping in the area (Riley, 1962; Baird and Cote,1964; Gillis, 1972) provided the incentive to remap and describe the rocks of the subbasin. This study presents some of the findings of the mapping programme.

Aims of Study

A general descriptive approach is presented here to describe the stratigraphy and sedimentation of rocks belonging to the Anguille and Codroy Groups in the subbasin. The aims of the study are:

a) to define the stratigraphy of the Anguille and Codroy Groups;

b) to describe and interpret the lithologies, lithofacies, paleontology and depositional environment of formations within the two groups;

c) to interpret the paleogeography and tectonic setting of the subbasin during the time interval when the two groups were deposited.

Methods of Investigation

Geologic information presented in the thesis was collected in a general and descriptive manner from outcrops mostly along coastal sections and along streams and rivers. Systematic bed by bed description did occur for some sections through stratigraphic units. This was accomplished using a metre stick and by calculation of bed thickness from measured distances, angle of slope and angle of dip (Krumbein et al., 1963, page 61).

Grain size of units was largely determined in the field by comparison with prepared grain size charts showing the divisions of the Wentworth (1922) scale. Roundness and sphericity of pebbles and sand grains was determined visually by comparison to the roundness sphericity chart of Powers (1953). Sorting was also determined visually using the maturity charts of Folk (1968) and Beard and Weyl (1973). The classification of bed thickness is that of Ingram (1954).

Paleocurrent directions measured with a Brunton compass were not corrected for the dip of beds or the plunge of folds unless dips exceeded 25° (Potter & Pettijohn, 1963) or plunge was greater than 10° and bedding dip greater than 45° (Ramsey, 1961). Steeper bedding was corrected in the field by rotating the direction into the horizontal plane before measuring direction. Trough crossbeds mostly record the axis of the trough; the rib formed at the intersection of two troughs was measured where observed.

Some macrofossils in the Codroy Group were identified by the author and by C.C.F. Fong by comparison with fossils described in the Horton-Windsor Memoir of Bell (1929) and in a recent publication by Moore and Ryan (1976). Other macrofossils were identified and zone determinations provided by Grace McGlynne, a graduate student at Acadia University, Wolfville, Nova Scotia. Conodont data and correlation within the Codroy Group was compiled from recent studies by Dr. Peter von Bitter, Royal Ontario Museum and spore assemblages were identified from the Codroy Group and Searston Formation by Dr. John Utting from I.R.N.S., Quebec City.

CHAPTER 2

STRATIGRAPHY

Part 1 - Introduction and Stratigraphic Problems

Historically, the Carboniferous rocks of the Bay St. George subbasin have been divided into three rock series or groups - Anguille, Codroy and Barachois (Hayes and Johnson, 1938; Bell, 1948; Riley, 1962; Baird and Cote, 1964). Emphasis in previous work was on the palaeontological and economic aspects of the strata and only the Anguille Group was previously internally subdivided (Baird and Cote, 1964).

It will be shown that deposition in the narrow Bay St. George subbasin occurred predominantly by fluvial processes. Rapid changes of facies and diachronous boundary relationships are, therefore, to be expected. Sedimentation was controlled by an interplay of tectonics, climate and depositional environment. Such factors have been shown to make lithostratigraphic definition difficult in Cansoan and Riversdalian strata of Nova Scotia (Belt, 1965). Similar problems have been encountered in the Bay St. George subbasin (1) in the upper part of the Codroy Group, (2) in defining the Codroy/Barachois contact, and (3) in subdividing the Anguille Group.

Structural complexities which have destroyed continuity of the sequence, and poor exposure, especially at critical places in the section, compound the problems.

A descriptive approach is taken to the lithostratigraphy within the Carboniferous succession of the subbasin. Lithology and succession in formations, and in members if they occur within formations, as for example in the Robinsons River Formation, are described first in general terms. Detailed subdivision of the sedimentary rocks of each formation into lithofacies is then presented. In these specific instances, detailed descriptions of lithofacies allow interpretation of depositional environment for various rock types. Lithofacies here is used in accordance with definition b in the 'Glossary of Geology' (American Geological Institute, 1972, page 412), as "A term used by Moore (1949, p. 17 & 32) to signify any particular kind of sedimentary rock or distinguishable rock record formed under common environmental conditions of deposition, considered without regard to age or geologic setting or without reference to designated stratigraphic units, and represented by the sum total of the lithologic characteristics (including both physical and biologic characters) of the rock." In each case, the lithofacies were defined from detailed measured sections and from descriptions of rock types made during the course of field mapping.

Part 2 - Anguille Group

The Anguille Group, a sequence of non-marine siliciclastic rocks, contains the oldest strata in the subbasin. It is mostly Tournaisian in age but also likely includes Upper Devonian strata, as first suggested by Belt (1968b, 1969). The group, which is defined lithostratigraphically, includes all Carboniferous strata that conformably underlie the basal Ship Cove Formation of the Codroy Group. The base of the group in the Anguille Mountains is not exposed;

rocks assigned to the Fischells conglomerate member sit, however, unconformably upon Grenvillian basement in the core of the Flat Bay anticline.

The group was first divided formally into three lithostratigraphic units by Baird and Cote (1964) but the stratigraphy is revised here to four formations (Table 1). This is necessitated because some important structural complexities were overlooked by Baird and Cote (1964). For example, their basal unit of red sandstones and slates, the Cape John Formation, can be shown to be inverted structurally and belongs instead to the uppermost redbed sequence of the group called the Spout Falls Formation in this report. The basal unit of the Anguille Group is redefined and renamed the Kennels Brook Formation. The Snakes Bight Formation of Baird and Cote (1964) is retained, but their Seacliffs Formation is now subdivided into two formations, the Friars Cove Formation and Spout Falls Formation.

Distribution

The Anguille Group (Figure 4) occurs in the following areas:

(a) in the Anguille Mountains and Bald Mountain, and northeastward adjacent to the Long Range fault as far as Barachois Brook;

(b) in the core of the Flat Bay anticline between Robinsons River and Flat Bay Brook;

(c) adjacent to the Steel Mountain anorthosite on Coal and Sheep Brooks;

(d) as thin deposits in the Port au Port - Stephenville area.

In the Anguille Mountains, all four formations of the group have been mapped. They are all present towards the northern end of the mountains and within the sequence northwest of the Snakes Bight fault. The uppermost Spout Falls Formation, however, is absent in the southeastern part of the Anguille Mountains. Here the Friars Cove Formation continues to the top of the group but contains some thin intercalations of strata typical of the Spout Falls Formation.

The four formations, as defined, are not recognizable in the Flat Bay anticline where the Anguille Group is represented by the Fischells conglomerate member (Baird, 1959). The relationship of this unit to the main Anguille succession to the south is still uncertain. Scant lithological evidence, however, suggests it is correlative with at least the upper part of the Spout Falls Formation, to which it is assigned (see also Baird and Cote, 1964). In the north of the subbasin on the Port au Port Peninsula and near Stephenville, thin conglomerate lies upon basement and beneath basal limestones of the Codroy Group and is also included in the Anguille Group.

Basal arkoses that underlie a local unconformity within the Brow Pond lentil (Figure 4) may be of equivalent age to part of the Spout Falls Formation. There is yet no biostratigraphic evidence to support this correlation.

Thickness

The thickness of the Anguille Group in the Anguille Mountains northwest of the Snakes Bight fault is approximately 2000 m. Southeast of this fault (Figure 4), the group thickens to at least 4000 m in the northeast of the mountains but thins rapidly southwestward to about 2800 m as the Spout Falls Formation lenses out. In the southwest, a deep drill hole in the Kennels Brook Formation provided evidence for an additional 2275+m to the section in this area. Here 3300+ m of the 4900+ m thick succession, however, consists of the basal Kennels Brook Formation. In contrast, in the northeast of the Anguille Mountains the 4500+m succession is dominated by the 3500 m thickness of the youngest Anguille formations, the Friars Cove and Spout Falls Formations. Significantly, this implies that the group is made up of basin-fill sequences of essentially two different ages.

The Fischells conglomerate member in the Flat Bay anticline is approximately 150-200 m thick, whilst only 1-2 m of conglomerate occurs along the northern margin of the subbasin.

Description of Formations

Kennels Brook Formation

Definition, distribution and thickness

The basal formation of the Anguille Group consists of red and gray sandstones, pebbly sandstones, conglomerates and slates with some brown mudstone and siltstone, and is here named the Kennels Brook Formation. It outcrops in the core of the Anguille anticline, along the base of the cliffs south of Snakes Bight, and as a narrow, linear belt of rocks immediately northwest of the Snakes Bight fault. The formation is not well exposed and hence no type section is designated.

The name is derived from Kennels Brook, which transects part of the unit and drains into Snakes Bight. The best exposures are found along Hynes Gulch, and Mary Ann's Gulch in the cliffs at Snakes Bight, where the uppermost beds of the formation are exposed. The base of the Kennels Brook Formation is not exposed in the area. A drill hole of 2275 m depth, sited on the crest of the Anguille anticline, did not reach the base of the unit (Union-Brinex, 1973). The top of the formation is placed at the lowest appearance of black shales in the overlying Snakes Bight Formation. The upper contact, which is well exposed at the base of the cliffs south of Snakes Bight, is sharp and apparently conformable, although locally it has been affected by thrust faulting. In this area, interbedded brown mudstones and siltstones compose the upper beds of the formation. Around the Anguille anticline, these lithologies are absent, and the top of the formation consists of green-gray to red sandstones and red siltstones.

The Kennels Brook Formation is at least 3200 m thick; 1000 m is exposed and the remaining thickness was penetrated in the Union-Brinex (1973) drill hole. Cote (1964) measured some very generalized sections on Lewis Gulch (246 m thick), at Hynes Pond on the crest of the Anguille anticline (714 m) and along the south side of Snakes Bight (92 m).

General lithology

The exposed portion of the Kennels Brook Formation consists in stratigraphic order of (A) brown weathering, well indurated, green-gray sandstones, pebbly sandstones and conglomerates, (B) red sandstones, red and green slates containing nodular caliche, and (C) brown silty mudstones and very fine sandstones, and a thin, discontinuous pale gray limestone bed.

Description of lithologies from the Union-Brinex drill hole (Union-Brinex, 1973) show similar rock types occur in the underlying succession. Fining-upward sequences of intercalated gray to red sandstone and red slates dominate thick intervals (up to 600 m). Other intervals up to 200 m thick consist of mostly gray and red, gritty and pebbly sandstones without red slates. Encountered at several levels in the drill hole, particularly in the lower 1000 m, are units up to 80 m thick of dolomitic, gray to green-gray, waxy shales and thin sandstones.

(A) Gray-green sandstone and conglomerate

The oldest strata exposed in the core of the Anguille anticline consist of thick units of green-gray, coarse grained sandstones and some pebbly sandstones and conglomerates. The coarse members are intercalated with thin units of red and green slates.

The arkosic and micaceous sandstones commence above a basal scour into the intercalated slates. The sandstones are generally massive with some lamination or thin bedding. Asymmetrical linguoid and sinuous-crested ripples are found that resemble the cuspate current ripples of Gustavson (1974) and the ripples of facies C_1 of the Donjek River (Williams and Rust, 1969). They are rare and, in some instances, covered by thin, locally discontinuous mud drapes.

The conglomerate and pebbly sandstone members are poorly sorted and consist of 5 to 36 cm thick beds. The pebbly sandstones are crudely interstratified with the conglomerates which form layers, lenses and scour infills within the sandstones. The pebbles are well to moderately rounded (Powers, 1953) and from 3 to 12 cm in diameter. They consist of white quartz, pink, finely crystalline, micaceous granite, coarsely crystalline pink granite, red granites, red hornblende granite, brown and red aphanitic rhyolite, banded rhyolite, brecciated rhyolite, green siliceous siltstone, and an occasional pebble of coarse grained, green sandstone, and pale gray granite gneiss. The largest clasts are generally white quartz. The interbedded red and green slates, which are up to 40 cm thick, overlie the sandstone members sharply. They appear to lack internal sedimentary structures.

(B) Green-to-red sandstones and slates

Green, green-gray to red sandstones and red and green slates replace the coarser beds upwards in the formation. The 1 to 3 m thick sandstones are fine to medium grained, arkosic and micaceous. They overlie erosional bases and fine upwards. Internal bedding is generally obscure but planar lamination, thin stratification, some large scale, planar-tabular crossbedding and trough crossbedding were noted. Trough crossbeds, 3 m wide and 50 cm thick at the base of the sandstones, decrease in size upward to 10 cm thick, 20 cm wide sets near the top of the beds. Dark gray shale clasts are common within the cross bedded sandstones.

The red and green slates, in units up to 6 m thick, are generally structureless but ripple cross-laminations, horizontal laminations, small yellow calcareous nodules (caliche) and mudcracks infilled locally with calcium carbonate are visible in some units.

(C) Brown mudstones and sandstones

In the southwest of the Anguille Mountains, brown mudstones, very fine sandstones and green siltstones form a sequence 12 to 90+ m thick above the gray and red sandstones and slates. The unit is wedge shaped and thickens southwestwards beneath the Snakes Bight Formation. It attains its maximum thickness of 90 m at Snakes Bight (Cote, 1964; Baird and Cote, 1964), thins to approximately 59 m at Hynes Gulch northwest of the Snakes Bight Fault, and is only 12 m thick (Cote, 1964) at Lewis Gulch. The unit is absent, however, beneath the Snakes Bight Formation along the headwaters of Brooms Brook on the southeast limb of the Anguille anticline. Here, black shales of the Snakes Bight Formation directly overlie gray and red sandstones and slates. The base of the unit is not exposed but red siltstones, which are more common towards the base of the Snakes Bight section (Cote, 1964), may suggest that it grades downwards into the underlying gray and red sandstones and slates. Bedded green siltstones typify the Hynes Gulch and Lewis Gulch sections suggesting that the interbedded brown mudstones and very fine sandstones are confined to the area near Snakes Bight.

Brown weathering, very fine sandstones occur in 10-40 cm thick beds and overlie planar to irregular bases, which in certain localities display scoop-shaped, shallow, and crosscutting forms. Internally, the sandstones display lamination which is often undulose. Ripple cross lamination and climbing ripple-drift of types A and B (Jopling and Walker, 1968) also occur. Convolution of the cross-lamination is common and dark brown liesegang rings are present in some of the sandstones.

Partings and beds of gray silty mudstone, a few centimetres to 75 cm thick are interbedded with the sandstones. The generally massive mudstones weather with a poorly-developed, hackly fracture, but, in some places, have a crude fissility. They contain a few lenses and boudinaged beds of green-gray siltstone. Mudcracks occur in the top of the mudstone and in the partings between sandstone beds. Rainprints are associated with some mudcrack horizons.

A single bed of laminated, shaly, pale gray limestone, 170 cm thick, occurs within the brown mudstone member in Mary Ann's Gulch, northwest of the Snakes Bight Fault. Alternating laminae of microspar and silty microspar form the laminations which are discontinuous and locally convoluted. The convolutions were flattened into the plane of the lamination during folding of the Anguille Group. No concretionary structures or fossils were found. Three kilometres to the northeast at Hynes Gulch, nodular gray limestone within laminated, very fine sandstones and siltstones appears to represent an extension of the unit. The nodular limestone is composed of very fine microspar with only scattered, angular, detrital silt grains.

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Unlike the description of lithology in succeeding formations, the Kennels Brook Formation has not been further divided into lithofacies.

Age and correlative deposits of the Kennels Brook Formation

The exact age of the formation is uncertain. The author is, however, in agreement with Belt (1968b, 1969) who suggested that the Kennels Brook Formation are equivalent to the pre-Hortonian strata in Nova Scotia which are, in part Late Devonian in age. This inferred pre-Hortonian age was based on miospores (Belt, 1969), presumably found in the single sample described by Cote (1964). The greater thickness of basal Anguille strata in the Bay St. George subbasin when compared to equivalent strata in the Horton Group of the Maritimes Basin may support a longer period of deposition and strengthens the suggestion of a Late Devonian age.

Cote (1964) and Belt (1968b, 1969) correlated the Kennels Brook Formation with the Craignish Formation of Cape Breton. In New Brunswick, redbeds of the Memramcook Formation (Varma, 1969) and the Perry Formation (Schluger, 1976), both Late Devonian in age, may be correlatives of the Kennels Brook Formation.

Elsewhere in Newfoundland, post-Acadian redbeds of Devonian age are found at a number of isolated localities. On the west coast of the island, the Lower Devonian Clam Bank Formation (Rodgers, 1965; O'Brien, 1975) occurs on the Port au Port Peninsula. Redbeds are also known along the south coast of Newfoundland in the Fortune Bay

(Calcutt, 1973), Gaultois (Greene and O'Driscoll, 1976), Harbour Breton (Greene, 1975), and Terrenceville (Bradley, 1962) areas. The Bay de l'Eau and Terrenceville Formations are dated by miospores as Late Devonian (Widmer, 1950; Bradley, 1962) and may correlate with the Kennels Brook Formation. These formations indicate the presence of regional molasse sedimentation peripheral to a central Newfoundland upland similar in shape to present-day Newfoundland.

Depositional environment of the Kennels Brook Formation.

Both Cote (1964) and Belt (1968a, 1969) interpreted the strata now assigned to the Kennels Brook Formation as deposits of a fluviatile environment. Belt (1968a) included them in his coarse grained fluvial facies positioned midway between basin-margin fanglomerates and finer basinward fluvial facies. The character of the succession suggests deposition by braided and meandering rivers, except locally at the top of the formation where the succession includes shallow lacustrine sediments in the southwest.

Massive or crudely stratified, scour-based, pebbly coarse sandstones in the lower part of the formation suggest deposition by gravelly and sandy braided streams (Rust, 1972; Miall, 1977). The structure and grain size of the coarse beds suggest that they were deposited as longitudinal bars during the high stage of stream floods (Doeglas, 1962; Williams and Rust, 1969; Smith, 1970, 1974; Rust, 1972; Miall, 1977). Structures typical of waning flood stages are rare. This, together with the fact that the contacts between sandstones and overlying red slates are sharp, may indicate rapid termination of stream flow in ephemeral streams. Minor mud-draped rippled surfaces and red slate layers probably formed in abandoned or minor channels in the braided channel system (Williams and Rust, 1969; Rust, 1972).

The repetitive character of the thick red sandstone - thick red slate succession in the middle of the formation suggests that the fluvial system later became a mature floodplain crossed by meandering rivers. The graded sandstones have basal scours, mudchip pebbles, parallel lamination and cross stratification. Sedimentary structures decrease in size upward, and the sandstones are overlain by red lutite. This sequence compares to the classical fining-upward cycles of Allen (1964a, 1965a, 1965b) deposited by lateral accretion beneath point-bar complexes of meandering rivers. Oxidized overbank deposits, represented by thick red lutites, were deposited on the floodplain. Nodular carbonate suggests immature caliche, typical of pedogenic horizons that form in soils under semiarid climatic conditions (Gile et al., 1966; Blatt et al., 1972; Leeder, 1975).

Although no palaeocurrent data were obtained because of generally inadequate bedding plane exposures, the arkosic composition of the sandstones and the dominantly acid-plutonic and silicic-volcanic clast composition of the pebbles suggest the source of alluvium was from pre-Carboniferous crystalline and volcanic rocks of central Newfoundland.

The bedded mudstones and very fine sandstone at the top of the formation form a wedge-shaped rock body in the southwest of the area and were probably deposited in a shallow lacustrine environment. This model cannot be supported by paleontological evidence or by definitive lithological features. The strata are restricted geographically to the present environs of the Snakes Bight fault, which is consistent with a narrow lake trending northeastward, particularly if the fault was active during deposition. Mudcracks that developed in both mudstone and sandstone units indicate that parts of the lake bed were periodically exposed. Rhythmic deposition of sandstones and mudstones point to alternating flood and interflood deposition. The tabular geometry, planar lamination and climbing ripple-drift lamination in the sandstones suggest that large volumes of fine sand were transported during floods and rapidly deposited as sheets over the muds (McKee, 1965). The sheets perhaps formed as floodwaters breached channels that cut across exposed dessicated mudflats. Lake level rose during each flood to drown the sand sheets and the lake margins and led to subsequent deposition of suspended mud. Laminated limestones were locally precipitated in the shallow lake waters. Nodular limestone formed pedogenically in porous sandstones when the lake level periodically fell as a result of evaporation in the semiarid climate (Gray, 1967; Freytot, 1973).

Snakes Bight Formation

Definition and distribution

The Snakes Bight Formation was the name proposed by Baird and Cote (1964) for a sequence of black lutites and gray sandstones that conformably overlie the Kennels Brook Formation. The formation derives its name from Snakes Bight, a small cove north of Cape Anguille. The formation occurs in the northwest dipping, faulted limb of the Anguille anticline and to the southeast of the Snakes Bight fault, where it is folded about the Anguille anticline between the fault and Brooms Brook. The upper beds of the formation are repeated along high angle faults near Cape Anguille and at the northeastern closure of the Anguille anticline. A section located along Hynes Gulch beginning about 2 km upstream of the mouth and continuing downstream for approximately 1.2 km is shown in figure 5 on foldout sheet A.

The formation begins where the black shales overlie either red beds, as around the southeast limb of the Anguille anticline, or brown mudstones, sandstones and green siltstones as in the southwest of the Anguille Mountains and just northwest of the Snakes Bight fault as far north as Lewis Gulch (Cote, 1964). At Snakes Bight the basal contact is sharp and was probably originally conformable, although it has been locally thrust. Elsewhere in the Anguille Mountain, the basal contact is not exposed, although the interval that conceals the contact on the south branch of Brooms Brook is only a few metres wide. The absence of brown mudstones and sandstones at this locality and elsewhere around the Anguille anticline may suggest the basal contact locally onlaps the underlying Kennels Brook formation. The upper contact is generally conformable and is placed at the base of a series of conglomerate beds which mark the base of the Friars Cove Formation throughout the Anguille Mountains.

Thickness

A section measured along Hynes Gulch indicates that the Snakes Bight Formation is about 785 m thick northwest of the Snakes Bight Fault. Southeast of the fault it is estimated from structural cross sections to be approximately 1000 m thick.

General lithology

The sedimentary rocks of the Snakes Bight Formation include black shales and mudstones, thin-bedded siltstones, thin- and thick-bedded gray sandstones, minor conglomerates, intraformational slump deposits and minor dolomitic and calcareous mudstones, argillaceous and arenaceous calcisiltites and calcarenites, and calcareous concretions. The sandstones are brown weathering, lithic arkoses to subarkoses; conglomerates consist of 1-3 cm diameter pebbles composed almost exclusively of white quartz and dolomite intraclasts.

The succession in the type section at Hynes Gulch and elsewhere northwest of the Snakes Bight fault consists of units of black lutite up to 27 m thick intercalated with sequences of interbedded sandstone and shale, up to 35 m thick. The sandstones have the general characteristics of turbidites (Bouma, 1962). Units of thick-bedded massive sandstones with pebble layers as great as 50 m thick are dispersed through the section.

The black lutites and interbedded sandstones and shales are concentrated in the lower 350 m of the type section. They are generally succeeded by thick intercalated units of mudstones and thick-bedded sandstones with only subordinate interbeds of sandstone and shale. In the upper 100 m, some of the thicker sandstones display crossbedding. Coarsening-upward sequences of mudstone overlain by thick sandstones are common in the upper 500 m. Shales become grayer in color and some evidence of subaerial exposure and dessication was observed locally near the top of the formation.

In the southwest of the area overlooking Snakes Bight, in Low Brook, Grebes Gulch and the Brooms Brook headwaters, the succession is broadly similar, commencing with some 60 m of thin-bedded siltstones, black shales and minor sandstone. This sequence passes upwards into generally monotonous, rhythmically interbedded sandstones and shales for at least 500 m (Plate 1). Chaotic deposits of intraformational mixtites are common particularly in the lower levels of the formation. The sandstones have the overall characteristics of turbidites and resemble Carboniferous flysch sequences of the Ouachita fold belt (Morris, 1974), southwest England (personal observation) and northern England (Walker, 1966a, 1978). Thick sandstone units interrupt the succession at intervals and coarsening-upward sequences of black lutites overlain by thick-bedded sandstones are also common (Plates 2 and 3). Toward the top of the Snakes Bight Formation in the southwest of the area, the thick coarsening-upward sequences are associated with sequences up to 12 m thick of laminated mudstones and siltstones containing rare sandstone beds. Thin dolomitic carbonates are also common. Here the upper sequence of the formation yields evidence of bioturbation and local dessication similar to that found in the type area near Snakes Bight.

Six lithofacies have been identified in the Snakes Bight Formation. They are (A) black mudstone-shale lithofacies, (B) graded sandstone/siltstone - shale lithofacies, (C) thick-bedded sandstone lithofacies, (D) thinly-bedded sandstone - shale lithofacies, (E) intraformational mixtite lithofacies and (F) carbonate lithofacies.

(A). Black mudstone - shale lithofacies.

Description of lithofacies A: This lithofacies, which comprises 25% to 29% of the type section (Figure 5 on foldout sheet A), is distributed throughout the formation. It consists of black, finely laminated and massive carbonaceous mudstones, siliceous mudstones and black shales in units 50 cm to 27 m thick. Both mudstones and shales are dolomitic and pyritiferous with microcrystalline dolomite making up 5 to 50% of the whole rock.

The laminated mudstones are composed of well to poorly sorted, microscopically-graded, muddy siltstones and silty mudstones. The mudstones are rich in carbonaceous material and are black. Delicate, carbonaceous, pyritic and yellow weathering, ferruginous dolomite laminae also occur. Small rounded and flattened pores are filled by microcrystalline dolomite. The dolomitic and siliceous nature of the laminae produces flat to undulose, smooth-surfaced outcrops that have a brittle, platy fracture. Light-colored siltstone and sandstone laminae, 1 mm thick, are found in many units and are replaced upward in coarsening-upward, mudstone - sandstone sequences by 1-10 cm beds of flat-bedded, finely laminated and rarely cross-laminated siltstones and sandstone.

Soft-sediment deformation (Plate 4) locally produced synsedimentary folds, faults, and brecciation. Fold axes at Cape Anguille strike approximately N-S and axial planes dip to the west from 25° to 70°. Sandstone dikes, which are a few centimetres to 140 cm wide and cross-cut at least 3 m of strata, occur at the top of the formation near Shoal Point, Codroy.

Mudcracks were noted at the base of sandstones intercalated with the laminated mudstones just below the upper contact of the formation at Friars Gulch and Hynes Gulch (Figure 5 on foldout sheet A). Mudcracks were not observed lower in the formation.

Interpretation of lithofacies A: Delicate lamination, lack of current-generated structures and the presence of pyrite and carbon-rich laminae suggest that the black mudstones and shales were deposited from suspension in stagnant, fetid, waters. Structures in the mudstones are similar to those formed in quiet basinal deposits of flysch basins (McBride, 1962) and in deeper-water deposits of ancient and modern lakes (Ludlam, 1967, 1974; Sanders, 1968; Dineley and Williams, 1968; Belt, 1968a; Donovan, 1975; Hubert et al., 1976; Sturm and Matter, 1978). Siltstone and sandstone laminae and flat-bedded, thinly laminated sandstones and siltstones in the mudstones, are probably distal turbidites (Walker, 1967) or deposits of other low-density flows (Sturm and Matter, 1978).

Syn-depositional deformation locally affected some units, formed folds and faults, and may have triggered the injection of sedimentary dikes, suggesting that the depositional environment was unstable and possibly frequently jolted by earth movements.

Mudcracks in mudstones near the top of the Snakes Bight Formation suggest subaerial exposure in the late stages of the evolution of the formation. However, these structures may be synaeresis (dehydration) cracks which can form subaqueously (Burst, 1965; Donovan and Foster, 1972). No other evidence of dessication was found so that subaerial exposure cannot be proven for intervals of this facies near the top of the formation.

(B). Graded sandstone/siltstone-shale lithofacies

Description of lithofacies B: This lithofacies consists of graded sandstone or siltstone beds regularly alternating with black shales. It constitutes 32% of the type section (Figure 5) and is also the major lithofacies in the first 300 m of the Snakes Bight Formation in the southwest part of the Anguille Mountains. Here the facies commences with up to 60 m of graded siltstone-shale beds, with some thin, graded sandstone beds, and is overlain by a fairly continuous sequence of graded sandstone-shale beds.

Siltstone-shale beds are 25-45 cm thick, of which 3-10 cm is siltstone (Plate 5). These dark gray, structureless beds overlie sharp, non-erosive, planar to slightly undulose bases. They grade upward into structureless, dark gray and black mudstones.

Sandstone-shale couplets form beds 15 to 50 cm thick, of which 10-40 cm are sandstone. Similar sandstones, 3-10 cm thick, occur in the siltstone-shale sequences. Cliff sections show that lateral continuity of beds is good (Figure 6; Plate 1). The sandstones are poorly sorted and vary from very coarse to very fine grained. They are predominantly medium grained in the northeast but appear to be finer grained in the southwest of the area.

The bases of the sandstones are usually sharp and planar but they also can be erosive and irregular. Non-erosive, sharp bases characterize the thin sandstones in the siltstone sequence. Sole markings occur and include linguiform, fan-shaped and crescentric flutes (Enos, 1969), chevron marks (Dunbar and Rodgers, 1957), longitudinal ridges (Dzulynski and Walton, 1965), groove casts and discontinuous grooves. Load casts are common and hieroglyphs are in many instances modified by soft-sediment deformation. The tops of many sandstones are sharp.

The thinner sandstones, particularly those interbedded with the graded siltstones, are internally composed of planar lamination and small scale cross-lamination. Sandstones of the rest of the succession, however, are normally graded and generally structureless. In the coarser beds, grading occurs from coarse or medium grained sandstone at the base to clean or muddy fine sandstone at the top. Mudclasts occur in some of these beds. Planar lamination and cross-lamination occur in the upper 3 to 10 cm of some beds, whilst others are formed exclusively of parallel lamination. Convolution of internal structure is common in both siltstones and laminated sandstones. Examination of photographs of the cliff sections from Snakes Bight to Cape Anguille suggests some graded beds occur in both coarsening and fining upwards bundles. On the other hand, in some parts of the sections, no trends are obvious.

Interpretation of lithofacies B: The rocks of this facies are similar to the monotonously interbedded classical turbidites and shales of silty and sandy flysch (McBride, 1962, 1970; Cline, 1970; Walker, 1970, 1978, 1979b; Walker and Mutti, 1973; Morris, 1974). Sandstones are typified by sharp bases, abundant sole marks and grading.

Most of the turbidites of this facies are classed as proximal AE or ABE turbidites (Bouma, 1962), because they are dominated by the massive interval A of the Bouma sequence (Walker, 1967). In contrast, the less common, flat-based, planar and cross-laminated BCE turbidites of the facies (Bouma, 1962) may have been deposited by waning turbidity currents (Normark, 1974), or by smaller flows.

The abundance of turbidites points to deposition in a deepish basin below wave base. Such a basin could have been marine or a deep lake (Gould, 1951, 1960; Houbolt and Jonker, 1968; Lambert et al., 1976; Sturm and Matter, 1978).

(C). Thick-bedded sandstone lithofacies.

Description of lithofacies C: Units up to 15 m thick, composed mostly of thick-bedded, massive sandstones make up this lithofacies and comprise about 18% of the type section. In addition, some stratified and crossbedded units occur, as do layers of conglomerate and pebbly sandstone. The facies is recognizable at intervals within the thick sequences of lithofacies B (Plate 1). In cliff sections at Snakes Bight, the sandstones are found above major concave-up scours more than 270 m wide, cross-cutting as much as 10 m of underlying lithofacies B strata (Figure 6). The facies also forms the most coarse, highest member of coarsening-upward sequences (Plates 2 & 3). The thick-bedded sandstones then thin and fine upward into lithofacies B turbidites, or are abruptly overlain by facies A mudstones.

The main sandstone units are constructed of beds 30 to 100 cm thick separated only by shale partings. Sandstone beds are poorly sorted, ungraded or graded, coarse or medium to fine grained. They usually overlie sharp, erosive bases; planar to cross-cutting bedding planes and channelling are common within units. Sole markings include bulbous flutes, frondescent marks (Dzulynski and Walton, 1965), groove casts and load casts. Internally, the beds are generally massive, though faint color variations and rare lamination suggest the presence of some amalgamated beds.

Intraclasts of shale and laminated dolomite, and granules of white quartz, rare silicic volcanics and granite are scattered in some sandstones. They may form pebbly sandstones and rarely conglomerates up to 70 cm thick in the middle of some units. Pebbles, mostly 1-3 cm and rarely 6 cm in diameter, are subrounded to angular. The intraclasts reach 20 cm in size but most are less than 10 cm in diameter and are flat and discoidal. Crude grading may be found in some pebbly beds. Crossbedding and planar stratification are present in thick sandstones that lie above thin-bedded turbidites and gray shales (lithofacies D) and below the basal conglomerate member of the Friars Cove Formation on Friars and Hynes Gulch. The 10-40 cm thick crossbeds occur as isolated or composite sets scouring into the underlying stratification. Three-dimensional exposures of the crossbeds, though uncommon, reveal trough-shaped sets.

Interpretation of lithofacies C: The thick bedded, massive character of many of the sandstones and their association with turbidites suggest that most of lithofacies C was deposited rapidly by mass emplacement of sandy detritus from dense turbidity currents or sandy debris flows (Middleton and Hampton, 1973, 1976).

Some of the thick-bedded sandstones overlie major scours within the turbidite sequence, possibly indicating deposition in channels or major episodes of basin instability which produced influxes of sand by slumping. The presence of coarsening-upward sequences capped by massive sandstones, however, suggests that deposition was associated with prograding deltas (Coleman, 1976) or with prograding sandy, deep-water fans (cf. Walker, 1978) at the foot of delta slopes (Normark and Dickson, 1976a, 1976b). The coarsening-upward sequence at the top of the type section of the Snakes Bight Formation shows thick sandstones, with current structures typical of fluvial processes. This evidence suggests that large, prograding, sandy deltas were common in the basin. Coarsening-upward sequences overlain sharply by mudstone or gradationally by thinner-bedded turbidites of facies B suggest that the delta-front or deep-water fan deposits were both abruptly and gradually abandoned. Abandonment may have been affected by channel switching or by reducing the sediment discharge along feeder channels.

(D). Thinly bedded sandstone-shale lithofacies.

Description of lithofacies D: This lithofacies consists of thin-bedded, often rusty weathering, very fine sandstones or siltstones interbedded with thin, black or gray shales. It forms only 5% of the type section. For the most part these lithologies alternate every few centimetres, but the beds also pinch out laterally. Sandstone beds are bounded by flat bedding planes with sharp tops. Most of the sandstones are cross-laminated or display parallel lamination overlain by cross-lamination; massive sandstone occurs at the base of some of the thicker beds. Soft-sediment deformation commonly produced load casts and flame structures as well as convolution of internal structures. Wavy bedding, boudinage, pseudonodules, wrinkling of bedding planes and linear, sand-filled cracks are common in the thin-bedded sequences. Fine plant debris and detrital micas are widespread.

This lithofacies is found in association with the thick sandstones of facies C in the type section of the Snakes Bight Formation and it also underlies the basal conglomerates of the Friars Cove Formation at Cape Anguille.

Interpretation of lithofacies D: The thinly-bedded, very fine grained sandstones and shales include many features suggesting rapid deposition on levees that lay adjacent to a deep-water channel along which sandy turbidity currents were funnelled (Mutti, 1977). This is supported by the presence of thin shales, the abundance of deformation, indicating rapid deposition, the wrinkling of bedding and the occurrence of linear cracks both possibly related to slope creep (tension), and the close association of the thinly-bedded lithofacies with the coarsest deposits of the Snakes Bight Formation (Walker, 1966b; Ricci Lucchi, 1975; Mutti, 1977).

Facies D is also overlain gradationally by crossbedded and stratified sandstones in coarsening-upward sequences near the top of the formation. Here, the thin-bedded sandstones and shales may be interpreted as prodelta deposits laid down in front of advancing distributary-channel sandstones (Coleman and Gagliano, 1965; Coleman, 1976).

(E). Intraformational mixtite lithofacies.

Description of lithofacies E: Small scale, synsedimentary deformation of both the fine and coarse sediments occurs throughout the formation. Larger scale, more extensive deformation, however, resulted in the formation of intraformational mixtite deposits. They are particularly common in the lower part of the formation in the southwest of the area where they comprise only a few percent of the sections of which they are a part. Here they lie within the turbidite sequences, in some places immediately beneath major scours.

The mixtites are up to 6 m thick. At one extreme they are composed of small, mostly mudstone intraclasts set in a mud matrix (Plate 6). At the other extreme they consist of an unsorted, chaotic mixture of large (up to 1 m in diameter) broken, boudinaged, attenuated, contorted, folded and rolled clasts all set in a muddy matrix. Lithologically, the clasts include sandstone, siltstone, shale and laminated dololutite (Plate 7). Shale and laminated fragments usually have ragged and tapered edges, whilst sandier intraclasts are smooth but angular. In rare instances fragments appear to be oriented. Near the top of one mixtite deposit, coherent sandstone beds were deformed to form tight, recumbent folds (Plate 8) which trend northeast. Irregular and transgressive bases occur but it is not unusual to observe undeformed, non-scoured sediments below the units. Some fine mixtite beds, about 60 cm thick, have erosive bases and grade upward into shales. They are intercalated with the turbidite sandstones.

Interpretation of lithofacies E: The mixtites are interpreted as deposits of incoherent slides. They were produced by mass movements of previously deposited sediments and, in this regard, are similar to the chaotic deposits of flysch and lacustrine basins (McBride, 1962, 1970; Morris, 1971, 1974; Corbett, 1973; Walker and Mutti, 1973; Ludlam, 1974; Walker, 1978; Link and Osborne, 1978). Their presence suggests that unstable conditions existed within the basin. Failure was probably triggered by earthquakes, violent storms or overloading (Dott, 1963).

Several kinds of deposit are observed: (a) thick, chaotic mixtites with large clasts, (b) thick, ungraded mixtites with small clasts and (c) thinner, graded, mixtites with small clasts grading into shales and interbedded with turbidites. The presence of all three types suggests that together they originally formed a progressive sequence which reflects the relative distance of transportation. A short distance of movement (Morris, 1974; Walker, 1978) and rapid "freezing" of the slide due to decrease in shear and/or void ratio (Crowell, 1957) produced mixtites with large clasts in which bedding was locally preserved. With increasing distance of movement, shearing and mixing caused disintegration, aided by incorporation of additional water. Fragments were reduced in size to form mixtites of types b & c similar to subaqueous mudflows (Morris, 1971) and debris flows (Middleton and Hampton, 1973, 1976). The thinner mixtites that grade up into shales may have been deposited from flows that evolved into turbidity currents (Hampton, 1972).

(F). Carbonate lithofacies.

Description of lithofacies F: Dolostones, ferruginous and silty dololutites, dolomitic concretions and calcareous siltstones, calcisiltites and sandy limestones comprise lithofacies F. The lithofacies appears volumetically to be a minor part of the succession. By virtue of its intimate intercalation and interlamination with mudstone, no estimate of its percentage contribution to the formation is made.

Silty ferruginous dololutites occur as laminae and beds 1-3 cm thick in facies A mudstones. The laminae, which are composed of fine microcrystalline and fibrous dolomite, are delicate, undulose and wrinkled. The 1-3 cm beds are structureless or laminated and are bounded by flat bedding planes. The dololutite beds are characterized by a clotted texture of ungraded microcrystalline dolomite, recrystallized in patches to slightly coarser dolomite. Carbonaceous stringers, scattered silt grains and rhombic crystals of dolomite are also present.

Dolomite concretions occur individually or in horizons in the lower strata of the formation. They reach 60 x 20 cm in size and are massive or laminated. Radial cracking typical of septarian nodules occurs on their undersides.

Yellow weathering, finely crystalline, massive dolostones occur most frequently near the top of the formation within laminated mudstones. They are locally bioturbated by randomly-oriented, straight, curved and branching tubular burrows that are filled by dolomitic mudstone from the overlying bed.

Pale gray, calcareous siltstones and calcisiltites, 1-5 cm thick, are infrequent and occur as thin beds within the turbidite succession. They have sharp, planar bases and are internally structureless, grading into fine lamination and in turn black shales.

Sandy limestones, 1-5 cm thick, are uncommon. They are bounded by flat planar bedding planes and are composed of sorted, sandy, calcarenites enclosing ooliths and intraclasts, some of which are of algal origin.

Interpretation of lithofacies F: The carbonate lithofacies is a minor part of the formation. The lack of marine fossils may indicate a non-marine (lacustrine) rather than marine origin.

The laminae and thin beds of dolomite found mostly in facies A mudstones indicate deposition in quiet water. Microcrystalline carbonate in the mudstones is suggestive of a fairly steady though variable rain of precipitate from the overlying water column. Lime- and magnesium rich laminae or beds probably formed when clastic or organic detrital influx into the basin was at a minimum during periods of drought in the surrounding areas (Muller et al., 1972; Muller and Wagner, 1978; Schafer and Stapf, 1978). During the droughts evaporative draw-down of lake level would have concentrated ions and promoted inorganic or biogenic precipitation of carbonates.

The abundance of dolomite in the lutites and sandstones suggests that the basin waters were rich in Ca^{2+}, Mg^{2+} and HCO_3^-. Aragonite or magnesium calcite are precipitated in modern, oligomictic or meromictic lakes during times of low water, high evaporation and a stable thermocline (Muller et al., 1972; Hubert et al., 1976). Dolomite and protodolomite form diagenetically after the precipitation of aragonite and high Mg - calcite (Muller et al., 1972). The latter minerals are known to be the primary precipitates of deeper water lakes (Muller et al., 1972; Schafer and Stapf, 1978). Patchy recrystallization of dolomite and the growth of dolomite rhombs in the rare limestones of the formation may indicate that the carbonate laminae were deposited either as calcite (Belt et al., 1967) or as high Mg - calcite. Such an origin has been postulated for the ferroan dolomites in the black mudstones of the Triassic East Berlin Formation, Connecticut (Hubert et al., 1976).

The fine intraclastic limestones and sandy calcarenites of the formation were probably deposited by turbidity currents, as they are intimately associated with turbidite deposits. A turbidite origin is not excluded for the graded calcarenites, even though its constituent allochems indicate a shallow-water origin. Cline (1970) has shown, for example, that detritus formed in shallow water is commonly found as exotic clasts in turbidite sequences.

Paleocurrents in the Snakes Bight Formation

Sole marks, including flute and groove casts, provide paleocurrent information. The data were collected in an unsystematic fashion from scattered locations in the Anguille Mountains (Figure 7). For the purposes of presentation, data are grouped into two areas, namely localities near Snakes Bight and those to the northwest of the Snakes Bight fault.

Southwestward to westward paleoflow dominates in the type section and in the area near Snakes Bight, although some paleocurrent indicators suggest local northwest paleoflow. At Cape Anguille some flute casts have a north-northeast vector of flow. Southerly paleoflow was recorded from beds at the top of the Snakes Bight Formation near the Cape Anguille lighthouse.

The main vectors probably relate to a northeasterly trending basin axis. This inference is supported by consistently oriented northeast-trending sedimentary dikes and by the axes of slump folds. An overall northwestward directed fan-shaped distribution for all flutes (Figure 7) suggests the source of the sandstones lay to the southeast.

Age and correlative deposits of the Snakes Bight Formation

The Snakes Bight Formation has been correlated with the Strathlorne Member/formation of Cape Breton (Baird and Cote, 1964; Belt, 1969). It also compares lithologically to the middle argillaceous member of the Horton Bluff Formation (Bell, 1960; Hesse and Reading, 1978) in Nova Scotia and to the rocks of the Albert Formation in New Brunswick (Greiner, 1962, 1974). The presence in the Snakes Bight Formation of some plant fragments comparable to *Aneimites acadica* Dawson, which is also common in the Horton Bluff Formation (Bell, 1960), strengthens this conclusion.

Depositional environment of the Snakes Bight Formation

The Snakes Bight Formation is interpreted as a lacustrine deposit as was first suggested by Baird and Cote (1964) and Belt (1968a, 1969). A model was not developed by those workers, however, and their interpretation leaned heavily on the lacustrine origin of time-equivalent strata in Nova Scotia (Bell, 1960) and New Brunswick (Gussow, 1953; Greiner, 1962). However, uncertainty has remained as to whether the Snakes Bight Formation could be marine rather than lacustrine. For example, the classical turbidite deposits of the formation resemble those in the marine Carboniferous of the Ouachita fold belt (Morris, 1974) the Variscan fold belt of southwest England (personal observation) and the Carboniferous of northern England (Walker 1966a, 1978). More importantly, the Snakes Bight Formation to date has not yielded non-marine vertebrates that are common in the time-equivalent Horton Bluff and Albert Formations of Nova Scotia and New Brunswick (Bell, 1960; Carroll et al., 1972; Hesse and Reading, 1978). These two formations also abound in shallow-water and subaerial indicators, both of which occur only rarely near the top of the Snakes Bight Formation. These facts altogether indicate that a marine model could be a viable alternative to a lacustrine one. The lack of a non-marine vertebrate fauna and other shallow-lacustrine features may be accounted for, however, if a relatively deep lake is postulated. The lack of marine fossils in any lithology, but particularly in the carbonates of both the Snakes Bight and overlying Friars Cove Formations, and the presence of plant fossils, provide strong support for a lacustrine environment. Many studies of modern and ancient lacustrine deposits have shown that turbidity current deposits contribute substantially to the infill of deep lakes (Houbolt and Jonker, 1968; Dineley and Williams, 1968; Normark and Dickson, 1976a and b; Lambert et al., 1976; Sturm and Matter, 1978; Link and Osborne, 1978). Consequently, a lacustrine model for the Snakes Bight Formation is favoured.

The Snakes Bight Formation is interpreted to have formed in a deep, perennial lake which was infilled by mudstones, silty and sandy turbidites and shales, intraformational slide deposits and thick sequences of deltaic sandstones.

The lake was probably a narrow, northeast trending body of water that formed in a narrow graben. The lake and the graben were bounded by the Long Range fault and an upland to the southeast, and an unidentified fault and an upland to the northwest in the area of St. George's Bay. Uplift of the Long Range Mountain area in the Devonian was suggested by Brown (1977) to explain pebbles of Long Range gneiss in the Windsor Point Group, itself deposited along the Cape Ray fault. Continued uplift of the southeastern upland during the Early Carboniferous is supported by plutonic, volcanic and metamorphic detritus in sandstones of the Kennels Brook and Snakes Bight Formations. The absence of Snakes Bight strata in the Flat Bay anticline restricts the lake to the axis of the subbasin so that (when corrected for shortening of strata by deformation) it was at most 30 km wide. A minimum length of 45 km is suggested by present outcrop distribution. However, the lake may have extended at least a further 30 km to the northeast if the Snakes Bight Formation continues beneath the northeastern closure of the Anguille anticline to subcrop beneath the Barachois synclinorium. Here it would be bounded by basement at Journois Brook and Steel Mountain and would, by necessity, decrease in width to 19 km. Belt (personal communication, 1981), however, has suggested the Anguille formations are absent from the northeast of the subbasin and the present rock distribution of the group reflects the original extent of the lake deposits (see Summary and Geologic History of the Anguille Group for discussion).

The widespread distribution of finely laminated, black pyritiferous and carbonaceous mudstones suggests quiet, stagnant, anoxygenic, deep-water sedimentation below the thermocline of a stratified, meromictic or oligomictic lake. Widespread and steady precipitation of carbonate occurred in the lake with short and long periods of high precipitation giving carbonate laminae and thin beds respectively. The carbonate strata probably reflect short to prolonged episodes of net evaporation (Muller et al., 1972; Hubert et al., 1976) at which time lake level was lowered, clastic input was at a minimum and ions were concentrated. A semiarid climate probably provided such conditions. This is supported by 10°-20° paleolatitudes postulated from paleomagnetic studies of the Carboniferous rocks of Maritime Canada (Roy, 1973; Smith et al., 1973; Irving, 1977).

This graben-bound Snakes Bight lake may be similar to the lakes of the southern end of the African rift valley (e.g. Lake Tanganyika), which exist in a semiarid savannah climate. There, lake level fluctuations of up to 12 m have been documented (Livingston, 1965; Degens et al., 1971; Ojany and Ogenda, 1973). Lack of evidence for subaerial exposure in the deposits means that the lake was deep enough to withstand intensive drought and drastic reductions of water levels. Absence of sulphate evaporites suggests the lake was rarely a closed system and was probably never hypersaline during its lifetime. It should be noted that gypsum crystals can be reduced by bacteria, as for example occurs in the present waters of the Dead Sea (Neev and Emery 1967)and hence may not show up in bottom sediments.

Laminated mudstones of lithofacies A were laid down over distal portions of the lake basin and along its flanks (Houbolt and Jonker, 1968; Ludlam, 1974; Sturm and Matter, 1978). Mud and fine silt was brought to the lake by riverborne inter- and over-flows and were circulated throughout the lake above the thermocline to settle out slowly as finely laminated 'varve-like' muds. Laminae and thin, laminated flat beds of coarser grained silt and sand in the muds were likely distal turbidites laid down mostly by low-density underflows. Such underflows are known to be the common style of discharge of rivers in flood, as documented by Sturm and Matter (1978) for Lake Brienz, Switzerland. Temporary disturbance of the thermocline by wind storms (Beadle, 1974), cooling of the lake, major slope failures or renewal of high inflow (Hsu and Kelts, 1978) produced thicker deposits of silty mudstone in the fine units.

For the most part, the lake was filled by sandy turbidites and by sands of prograding deltas (Lithofacies B and C). The turbidites dominate the lower 300-500 m of the succession in the type section and in the southwest part of the Anguille Mountains. Southwestward-directed paleoflow, southwestward fining of sandstones and the apparent upward coarsening of the succession from silty to sandy flysch support the deposition of a southwestward prograding prism of turbidites along the deep axial zone of the subbasin. Slump folds and sandstone dikes support a northeast trend to the subbasin and sufficient slopes ($<5^{\circ}$, Lewis, 1971) to initiate major slope failures and production of intraformational mixtites (Lithofacies E). The variety of clast types in the mixtites suggest mass movement of basin-flank muds (Ludlam, 1974), bedded turbidite deposits, parts of sublacustrine fans (Houbolt and Jonker, 1968; Link and Osborne, 1978) and deltaic deposits (Normark and Dickson, 1976b; Link and Osborne, 1978; Sturm and Matter, 1978).

Sediment for the turbidite succession was provided by a major river, or rivers, that probably entered the lake in the northeast. Minor paleocurrent vectors directed towards the northwest also suggest that sediment also entered the lake along its southeast margin.

Coarse sediment reached the axis of the deep lake in turbidity currents and likely travelled considerable distances (Gould, 1951, 1960; Houbolt and Jonker, 1968; Normark and Dickson, 1976a and b; Lambert et al., 1976; Sturm and Matter, 1978). The turbidites were probably generated by the following mechanisms:
(1) formation of a turbid layer of suspended sediment, several metres thick, on the upper slopes of the delta (Normark and Dickson, 1976a and b) as a result of wave agitation;
(2) failure and down-slope movement of delta deposits because of slope overloading, earth tremors or severe storms (Dott, 1963), particularly when lake levels were lower (Degens et al., 1971; Kelts and Briegel, 1971; Ludlam, 1974; Normark, 1974); and (3) high-density underflows that resulted from exceptional discharge of flood-swollen rivers into the lake (Lambert et al., 1976; Sturm and Matter, 1978). The underflows passed across the deltas along channels (cf. Houbolt and Jonker, 1968; Forstner et al., 1968; Lambert et al., 1976; Sturm and Matter, 1978) and deposited thick AE and ABE turbidites at the foot of the delta.

Channels with widths of several hundred metres and depths of more than 10 m have been measured in modern lakes and are known from seismic and bathymetric studies to shift position, with abandoned channels later filled by sediment (Hsu and Kelts, 1978). The thickest turbidites are commonly laid down near the foot of the delta where modern deposits can be up to 1.5 m thick (Sturm and Matter, 1978). The thickest turbidites in alpine lakes are correlated with catastrophic river floods (Sturm and Matter, 1978) which occur once or twice a century and carry a volume of sediment many times greater than the average discharge of normal floods. Consequently, the succession consists of thick sands separated by intervals of laminated, 'varve-like' muds and thin bedded, laminated, silty and fine sandy beds that were generated by low density underflows of rivers in seasonal flood.

The thickness and regular bedded nature of the turbidite succession in the Snakes Bight Formation, however, suggests that the turbidite-generating events supplied density deposits at frequent, regular intervals to the axis of the deep lake. This may reflect flashfloods over source areas at intervals of a few years or tens of years moving large volumes of detritus, as is common in semiarid climatic areas (Leopold et al., 1964; Baker, 1977). Inadequate vegetation cover in the source areas would tend to enhance the sudden catastrophic affect of these violent rainstorms when precipitation and flooding may be many times normal and slope erosion increased substantially (Leopold et al., 1964; Karcz, 1972; Baker, 1977). Consequently, sand- and mud- sized detritus was likely swept from hillsides and carried by steep-gradient streams directly to the lake.

A lake with steep lateral flanks is envisioned. This concept is in keeping with the volume of turbidites and slide deposits in the lower succession. Deltas probably formed at the basin margins but were affected by frequent resedimentation of the delta front sands to deeper water. Sublacustrine fans are known to form in the deep waters of lakes in front of deltas, and have been documented in modern (Houbolt and Jonker, 1968; Normark and Dickson, 1976a) and ancient lakes (Link and Osborne, 1978). The presence of coarsening-upward sequences of turbidites (Walker, 1978) and the presence of major scour surfaces overlain by thick-bedded turbidite sandstones and intraformational mixtites suggest that these rocks were deposited as sublacustrine fans in the deep axial zone of the Snakes Bight lake. The scours may represent episodes of major erosion accompanying influx of very large turbidity currents, with each scour overlain by the lobe of a fan. Overlapping of scour-based turbidite bundles might imply that the locus of deposition was linked to repositioning of delta channels.

Sediments that can be interpreted as delta deposits laterally equivalent to the lower turbidite succession have not been found to date. Nevertheless, the deeper parts of the axial zone of the lake were probably infilled by the time that coarsening-upward sequences of mudstones and sandstones were laid down in the upper half of the formation. These sequences of black, laminated mudstones interbedded with thin siltstones and sandstones and capped by thick-bedded sandstones are interpreted as the subaqueous deposits of prograding sandy deltas, that were laid down in the shallower, yet still stratified, lake. Northward paleoflow in some of the coarsening-upward sequences suggests that the deltas were associated with rivers entering the lake from its southeast margin.

Once the lake had shallowed sufficiently, the thermocline was destroyed more frequently. Organic activity and deposition of gray shales occurred in shallower waters as circulation and oxygen content improved. Thick, delta-distributary sand deposits prograded southwestward at the northeast end of the lake forming coarsening-upward sequences, with the first indications of subaerial (lithofacies A) and fluvial processes (lithofacies C). Dolostone beds formed during prolonged dry periods (Muller et al., 1972; Schafer and Stapf, 1978) in the shallow water. At the southwest end of the lake, black to gray shales and thin turbidites (lithofacies d) were overlain by the basal debris flows and sandy turbidites of the Friars Cove Formation. deeper-water conditions might have prevailed there somewhat longer.

Although information is still very preliminary, the depth of the lake possibly exceeded 100 m, to allow sufficient slope and depth for deposition of the thick turbidite sequence. A deep, large lake would also readily maintain a stratified water column. This fact would inhibit the lake waters from becoming hypersaline during prolonged periods of drought. active basin subsidence and adequate fresh-water inflow could maintain lake depth, even if the rate of sedimentation was high. Gradual shallowing of the Snakes Bight lake suggests that subsidence possibly decreased, at least temporarily, toward the end of its history. A lake of the size and depth envisaged would thus remain a major geomorphic feature for perhaps hundreds of thousands of years. Deep water sedimentation rates of up to 6 m per 1,000 years occur in some alpine lakes, e.g. Lake Constance (Muller and Gees, 1970; Reineck and Singh, 1975), whilst deep lakes of the African Rift Valley have rates of 30 cm to 5 m per 1,000 years (Muller and Wagner, 1978). Post-compaction thickness of the laminated lacustrine shales of the Triassic East Berlin Formation gave a rate of 35 to 45 cm/1,000 years (Hubert et al., 1976). Facies A mudstones, 180 m thick, occur in 22 units each 50 cm to 27 m thick in the type section of the Snakes Bight Formation. Allowing a slightly higher post-compaction sedimentation rate of 50 cm per 1,000 years for their deposition, a time duration of at least 360,000 years is possible for the lake. Over this interval, individual mudstone units may have taken between 1,000 and 53,000 years to be laid down.

Friars Cove Formation

Definition and distribution

The Friars Cove Formation is the name used by Knight (1983) for a sequence of gray sandstones, conglomerates and shales with minor carbonates and redbeds that conformably overlies the Snakes Bight Formation. It was previously assigned to the lower gray sandstone sequence of the Seacliffs Formation (Baird and Cote, 1964). In the northern half of the Anguille Mountains the Friars Cove Formation underlies redbeds of the Spout Falls Formation and here it comprises the third of the four formations in the Anguille Group. South of the "round valley", however, Spout Falls redbeds pinch out into a few thin units so that the Friars Cove Formation forms the uppermost unit of the Anguille Group, overlain by the basal limestones of the Codroy Group.

The formation is named after Friars Cove on the northwest coast of the Anguille Mountains. A section located on the gulch draining into the cove and beginning 0.7 km upstream and continuing to the shore where the upper contact occurs is illustrated in figure 8 on foldout sheet A. Well exposed sections occur in many adjacent valleys, on Grand Daddy's Brook, on Brooms Brook and its tributaries, and on Codroy Island. The formation has been mapped throughout the Anguille Mountains.

The lower contact of the Friars Cove Formation is placed at the base of a widely distributed conglomerate unit. It is conformable with the underlying Snakes Bight Formation although at Cape Anguille significant erosion occurred beneath the conglomerates (Plate 9). The upper contact with the overlying Spout Falls Formation is gradational. It is placed above the last thick unit of interbedded gray sandstones and shales at the base of the first thick (>1 m) red sandstone unit interbedded with green-gray sandstones.

Gray beds similar to the Friars Cove strata appear to overlie redbeds of the Spout Falls Formation on the southeast side of Bald Mountain and along the north branch of the Codroy River near the Long Range fault. The gray beds are here included in the Spout Falls

Formation on the accompanying geologic map. The relationship is believed to reflect the interfingering of the two formations in the middle of the Anguille Mountains. Alternatively, the gray beds may have been uplifted into their present position along an undetected fault to the northwest (Knight and Fong, 1975).

Thickness

The Friars Cove Formation is approximately 500 m thick in the vicinity of the Friars Gulch section. It is calculated using measured sections and structural cross sections to thicken southeast of the Snakes Bight fault to 690 m near Codroy and 1300 m in the northeast Anguille Mountains. Baird and Cote (1964) estimated 840 m in the area of Grand Daddy's and Brooms Brooks.

General Lithology

The Friars Cove Formation consists predominantly of buff- to brown weathering, gray, calcareous, arkosic and quartzose sandstones, together with some conglomerates, gray shales and minor red beds and carbonates.

The formation begins with a widespread, 2 to 32 m thick basal sequence of interbedded conglomerates and sandstones (Figure 9). Near Friars Gulch (Figure 8) and the "round valley", they conformably overlie thick-bedded sandstones (lithofacies C) of the Snakes Bight Formation. At Cape Anguille, however, the conglomerates and sandstones (Figure 10) lie upon the locally eroded, thinly bedded sandstone-shale lithofacies of the Snakes Bight Formation.

Pebbles and locally boulders ranging from a few centimetres to more than a metre in size occur in the conglomerates. They are composed of white quartz, pink and gray granites, foliated porphyritic granites, brown to red silicic volcanics, white sedimentary quartzites, gray limestone, dolomite, dolostones and chert. The largest boulders consist of granite and quartzite and have been measured up to 130 x 89 x 72 cm in size. The quartzite, carbonate and chert are clearly derived from the Cambro-Ordovician platformal succession that now lies north of the subbasin. Cambro-Ordovician clasts are particularly abundant at Cape Anguille and Lewis Gulch (Cote, 1964) as are pebbles of gneiss, diabase and ultramafic rock and green argillite. Most of these clasts are absent northeast of the "round valley" where the pebble suite is dominated by silicic volcanic and acid plutonic rocks. Granitic and other large clasts are almost always angular. Limestone and quartzite pebbles possess high sphericity and roundness.

Above the basal member, the succession varies in lithological composition from north to south along the Anguille Mountains. In the north the first 180 m of the succession is dominated by thick, planar stratified and crossbedded, medium to very coarse sandstones containing minor conglomerates and separated by thin shales. Thick units of gray to locally black shales, rich in mudcracks and plant debris and containing thin sandstones, compose the middle 118 m of the formation. The Friars Cove Formation is then completed by 180 m of crossbedded and planar laminated, gray sandstones. These rocks locally fine upward and are colored red in several units. Gray shales are thin. Rare stromatolitic dolomites occur in the basal conglomerate and in the overlying succession.

In the south of the Anguille Mountains, the succession above the basal member is dominated by thick units of either thick-bedded and massive, or thinly stratified and crossbedded, gray sandstones separated by subordinate gray shales. The gray, fluviatile succession is generally monotonous, but multilithological sections also occur especially on Codroy Island, Grand Daddy's Brook and in small, tributary brooks of Brooms Brook. Ripple-bedded quartzose sandstones, thinly bedded 'turbidite-like sandstones' and gray shales join the thick gray sandstones in these multi-component sections. Crawling trails and burrows occur with ripple-marked sandstones and shales on Codroy Island. Dessication cracks are found in some of the lithofacies. Arkosic grits and small pebble conglomerates, rich in fresh pink feldspar and yellow limonitic clasts, are locally present and minor redbeds occur most commonly throughout the top 310 m of the formation.

Seven major lithofacies are defined in the Friars Cove Formation and are found both in the type section and in exposures elsewhere throughout the map area. They are (A) conglomerate - pebbly sandstone lithofacies, (B) thick-bedded sandstone lithofacies, (C) rippled sandstone lithofacies, (D) shale - sandstone lithofacies, (E) red sandstone and pebbly arkose lithofacies, (F) carbonate lithofacies and (G) well-sorted, sandstone-siltstone lithofacies.

(A) Conglomerate-pebbly sandstone lithofacies.

Description of lithofacies A: This facies, which marks the base of the formation at Cape Anguille and northeast of the "round valley", is composed of pebble to boulder conglomerates, pebbly sandstones, and calcareous, medium to very coarse-grained sandstones (Figure 9). It contributes less than 2% of the strata in the formation.

Two associations occur. The first association of ungraded and graded conglomerates and thick sandstones is exposed at Cape Anguille, along Grand Daddy's Brook and in scattered localities near Brooms Brook. The second association of lenticular-bedded conglomerates and sandstones can be seen northeast of the "round valley" (K 310, Figure 9) and along Lewis Gulch, southeast of the Snakes Bight Fault. It also occurs in sandstones higher in the Friars Cove Formation northeast of Morris Gulch. These associations are discussed separately below.

At Cape Anguille, the ungraded and graded conglomerate-sandstone association consists of conglomerate beds, 1 to 5 m thick, intercalated with 1-3 m thick sandstones. The ungraded conglomerates, which overlie scoured (Plate 9) to locally planar bases, are poorly sorted, massive, matrix-supported deposits. Their irregular thickness is due to hummocky tops (Plate 10). The largest clasts seen in lithofacies A are found in the ungraded conglomerates where they lie preferentially near the top of beds (Plate 10). Large, internally-bedded sandstone rip-up clasts are also observed. Sediments beneath the conglomerates are locally deformed; imbricated shale tongues protrude into the base of one conglomerate, and conglomerate dikes (Plate 11) cut underlying sandstones.

Normally and inversely graded conglomerates (Plates 12 and 13) occur in beds 15 to 150 cm thick interbedded with sandstones. These uncommon conglomerates consist of pebbles generally smaller than 15 cm in diameter.

The conglomerates of the first association are generally in sharp contact with overlying, lenticular grits and medium to very coarse, sandstones. The sandstones may be graded, massive (Plate 12) crudely stratified, thin bedded or laminated (Plate 10). Many beds grade from a thin, basal, small-pebble conglomerate up into thick, laminated or massive sandstone (Plate 14). Crossbeds (Plate 15) and climbing ripple lamination occur at the top of some sandstone beds above parallel lamination with parting lineations. Climbing ripple drift of types A and B (Jopling and Walker, 1968), associated with straight, low-amplitude ripple marks, was observed in one fine grained sandstone bed. The angle of climb of the type B ripple drift increases up through the bed from 35° to 48°; type A replaces type B structure in a downcurrent direction. Lunate and sinuous, asymmetrical ripple marks, rib and furrow, and oriented plant debris are also seen on bedding surfaces.

Convolute bedding, deformation of basal bedding planes, dish structures (Stauffer, 1967) and pillar structures (Lowe, 1975) (Plate 16) occur in the thicker sandstone beds.

Conglomerates containing lenticular sandstones, and sandstones with thin lenses of conglomerate form the second association (see K

310, Figure 9). The conglomerates have erosional bases and occur in beds 40 - 200 cm thick. They commonly show better sorting than the first association, with pebbles less than 10 cm and rarely up to 22 cm in diameter. Structureless or crudely bedded conglomerates contain lenses, up to 20 cm thick and 100 cm wide, of medium to coarse grained, gray sandstone. The conglomerates gradually become thinner up-section and, in some instances, consist of a single layer of pebbles locally thickening to 30 cm in erosional depressions within sandstones. The sandstones are 30-60 cm thick, structureless or horizontally stratified, with scattered pebbles. Crossbedded sandstones occur immediately above this association and contain some thin red units.

Interpretation of lithofacies A: The rocks of the ungraded and graded conglomerate-sandstone association at Cape Anguille are interpreted as the deposits of debris flows and thick, high-density, turbidity currents. The erosive bases and the generally structureless, unsorted, coarse, matrix-supported detritus suggest that the conglomerates were deposited by viscous mass flow processes (Middleton and Hampton, 1973, 1976; Walker, 1975b). Scouring and incorporation of partially consolidated strata occurred as the flows moved along channels. Hummocky tops, retention of bedding in sandstone rip-ups, and the preservation of shale tongues at the bases of conglomerate layers probably indicate that the beds were deposited rapidly. Deposition probably occurred when escaping pore fluid caused strength of the debris to increase above the local shear stress. A decrease in the slope of the depositional basin (and therefore a decrease in shear stress) may also have been a significant factor. The debris flows possessed sufficient matrix strength and buoyant support to maintain the largest particles toward the top of the flows during transportation.

The normally and inversely graded conglomerates, overlain by stratified sandstones, resemble the resedimented conglomerates of Walker (1975a and b). Abundant rounded pebbles of sedimentary quartzite and of carbonate imply that some clasts were previously shaped by fluvial or shallow shoreline processes. Alternatively, they may have been derived from older conglomerate strata such as the conglomerates of the Cambro-Ordovician Cow Head breccias.

The thick, massive and crudely-stratified, often graded, pebbly sandstones and the thin pebble beds that grade upward into massive and laminated sandstones were probably deposited by decelerating turbidity currents (Middleton and Hampton, 1976). Rapid deposition trapped fluids, which then escaped to produce dish and pillar structures (Lowe and LoPiccolo, 1974; Lowe, 1975). Types A and B ripple drift formed as the turbidity currents decelerated and fine sediment was deposited rapidly from suspension. A reduction of flow velocity or increase in suspended sediment fallout caused the angle of climb of type B ripple drift to increase. A decrease in sediment load probably caused the change from the type B to the type A structure in a downcurrent direction (Jopling and Walker, 1968).

Crossbeds formed either by the reworking of sand beds into megaripples by the tails of the turbidity currents or by later, cool, river currents that flowed beneath warmer, surface lake waters along the sublacustrine channels.

The lenticular-bedded conglomerates and sandstones of the second association are characterized by their coarseness, their general lack of structure, an abundance of scouring, and a local association with thin redbeds. They were probably deposited in a shifting fluvial regime (Clifton, 1973) consisting of braided streams (Williams and Rust, 1969; Bull, 1972). These structureless deposits were probably laid down in longitudinal bars (Doeglas, 1962; Smith, 1970; McDonald and Banerjee, 1971; Rust, 1972; Hein and Walker, 1977; Miall, 1977) and the conglomerates, one pebble thick, may be diffuse gravel sheets (Hein and Walker, 1977) deposited in the upstream reaches of sandy braided channels.

(B) Thick-bedded sandstone lithofacies.

Description of lithofacies B: Gray and green, calcareous, arkosic and subarkosic sandstones with subordinate pebble beds, in units up to 40 m thick, form this lithofacies. They comprise 52% of the type section and 36% of the section on Codroy Island (Cote, 1964). The sandstones show massive thick bedding, planar thin stratification, crossbedding and some lamination. Thick-bedded sandstone units in the southwest of the area contain mudclasts and some pebbly horizons; the units are usually completed by cross-stratified beds. Planar-stratified sandstones (Plate 17), with some pebble beds, characterize the basal 180 m of the type section of the Friars Cove Formation.

The 40-150 cm thick, graded and ungraded sandstones on Codroy Island (Sections 3 and 4, Figure 11 on foldout sheet A) are mostly structureless but may be laminated near the tops of beds (Plate 18). Flute and load casts occur on sharp bases and thin shales separate beds in some units. Crossbedded, massive grits and small-pebble conglomerates occur in channels in the middle of the units. They are composed of angular to subrounded fragments of white quartz, pink feldspar, granite, silicic volcanics, red and green quartzite, gray limestone and locally derived, yellow weathering, limonitic intraclasts. Mudcracks are found in shale partings near the top of one unit.

Trough crossbeds, 15-40 cm thick, and planar-tabular crossbeds, 40-200 cm thick, occur in the upper half of the sandstone sequences (Sections 3 and 4, Figure 11). The latter have graded, 1-8 cm thick foresets. Rare laminated sandstones are present in the middle of units where they are characteristically well sorted, contain parting lineations and are as thick as 5 m.

The planar-stratified, medium to very coarse sandstones (Sections 1 and 2, Figure 11) display horizontal to slightly inclined stratification (Plate 17) defined by grain size variation such as normal grading. Parting lineations are rare, and broad, low-angle, planar scours crosscut units. Small solitary and composite trough crossbeds are situated near the top of some units.

Solitary pebbles and generally clast-supported conglomerates lie within the sandstones in the Friars Gulch type section. Cobbles as large as 16 cm in diameter straddle the conglomerate-sandstone contacts (Plate 19; Section 1 Figure 11). A roughly triangular-shaped intraclast of conglomerate, 24 cm x 24 cm in size, occurs in sandstones in the same interval of the type section.

Gray, fining-upward, 2-4 m thick, arkosic and micaceous sandstones occur with shales in the middle part of the type section. They commence, above a basal scour, with a mudclast lag succeeded by trough crossbedded and some planar-laminated units.

Near the top of the Friars Cove Formation, multistory sequences of gray, trough cross-stratified and planar-laminated sandstones predominate (See Figure 8, and Section 7, Figure 11). Ripple cross-lamination, plant rootlets and red coloration occur at the top of some units.

Interpretation of lithofacies B: The characteristics of lithofacies B suggest that the thick-bedded sandstones were deposited in fluvial channels and as deltaic sand bodies around the margin of a lake.

The association of shallow lacustrine deposits with the thick, massive and crossbedded sandstones on Codroy Island and with the thick, planar-stratified sandstones in the lower 180 m of the Friars

Cove type section implies that these thick sandstones were laid down along the margins of the Snakes Bight - Friars Cove lake.

On Codroy Island, massive, thick-bedded sandstones overlain by minor laminated and, in turn, crossbedded sandstones form a vertical succession of facies units. There lithofacies B sandstones, with sharp, locally fluted bases and abundant intraclasts, resemble thick proximal turbidites (Walker, 1967). Rapid deposition of large quantities of sand was most probably affected by powerful currents (Banerjee, 1977). Interbedded shales, some of which are mudcracked, may indicate distinct depositional pulses and generally shallow water depth. This seems to suggest the presence of high-density underflows discharging from a river mouth into a shallow lake. Rapid deceleration possibly occurred as the turbidity currents spread out beyond the river mouth. In other units, where shale is absent, the upward thickening of beds interspersed with some grits and conglomerates provides evidence that some of the sand bodies were prograding rapidly across the lake margin.

Above the massive, thick-bedded sandstones, planar-laminated sandstones with parting lineations are overlain by crossbedded deposits. These rocks seem to indicate that flow conditions changed as distributory channels were established or infilled, accompanied by a decrease in bed load and current velocities (Harms and Fahnestock, 1965; Southard, 1975). The large, planar crossbeds were probably deposited as cross-channel, transverse or linguoid bars (Cant and Walker, 1978; Smith, 1971, 1972; Collinson, 1970b) in sandy braided channels. Trough crossbeds formed within megarippled sand waves (Harms, 1975) that migrated along channels (Cant and Walker, 1978). Similar sequences of massive, thick-bedded sandstones overlain by heterogeneous crossbedded sandstones have been illustrated by Kelling and George (1971) from fluvial distributary channels of the Pembroke Coalfield, South Wales. There, the massive sandstones are also interpreted as flood deposits within channels that scoured into a delta front sequence, and there they are overlain by crossbedded sandstones thought to have been deposited by migrating dunes and bars.

The planar-stratified sandstones in the Friars Cove type section were deposited by traction currents which were strong enough to transport both pebbles and sand (Harms and Fahnestock, 1965) and to erode and move large rip-up clasts of partly consolidated conglomerate. The pebbles rolled along the bed, whilst medium to very coarse sand was carried in suspension (Walker, 1975a, Figure 7-3, page 140). As flow decelerated, pebbles ceased rolling and were deposited within sand beds characterized by upper flow regime plane beds (Simons et al., 1965; Harms, 1975; Southard, 1975). Where large quantities of pebbles were moved as bed load, pebble beds were formed.

The thick, planar-stratified sandstones possibly formed in large deep channels with a fairly steady flow strength (Rust, 1972; Harms, 1975; Southard, 1975). Ephemeral streams (Picard and High, 1973), which commonly possess sufficient surplus energy to erode and transport large objects during flood (McKee et al., 1967; Williams, 1971), may also produce such deposits. Broad scour surfaces in the planar-stratified sandstones suggest the deposits were built up by repeated influxes of sediment under similar flow conditions. This may support the latter interpretation.

Finally, sandstone deposits of the delta plain include the fining-upward sandstones within shales and multistory sandstones in the upper part of the type section of the Friars Cove Formation. The former bear the characteristics of deposits of meandering river channels (Allen, 1965a; Walker, 1979a). The latter resemble facies in the overlying Spout Falls Formation and were probably laid down by sandy braided streams.

(C) Rippled sandstone lithofacies

Description of lithofacies C: This lithofacies, 50-500 cm thick, is best developed south of the "round valley", particularly on Codroy Island (Sections 3 and 4, Figure 11 on foldout sheet A) where it forms less than 2% of the section. It begins with a sharp to locally erosive base above lithofacies B sandstones and passes gradationally upward into shales and thin sandstones. In places, a bed of crossbedded sandstone overlies the basal scour. Otherwise, lithofacies C consists of well sorted, fine, locally dolomitic, quartzose sandstone beds. These beds are arranged in 28-84 cm thick units of rippled, thin-bedded sandstones (Plate 20) alternating with 15 cm beds of planar-laminated sandstones with mudstone partings. Straight, sinuous, bifurcating and interfering symmetrical ripple marks cover complete bedding planes. They are characterized by 2-12 cm wavelengths, 0.25 to 1.5 cm heights and ripple indices (Tanner, 1967) of 4 to 12. Linguoid ripple marks, rib and furrow, some type A ripple drift (Jopling and Walker, 1968) and ripple cross-lamination associated with scoop-shaped scours also occur. Some ripple marks are flattened or gently rounded. Smooth and mudcracked mudstone and thin dolomite or limestone drapes fill troughs or cover rippled surfaces (Plate 21).

Interpretation of lithofacies C: The well bedded and sorted, ripple-marked sandstones with locally developed basal scours and the crossbedded sandstones are interpreted as the record of shallow-water sand flats formed by currents that reworked the top of facies B sandstones. Interference ripple patterns, ripple symmetry and the flattened shapes of the ripples together suggest that the ripple marks were modified by later currents or by gentle, oscillating wave activity. Mud drapes were deposited in still water and limestone or dolomite precipitated when the shallow water covering the rippled sands became increasingly saline and alkaline due to evaporation (Liebermann, 1967; von Borch, 1976). Exposure and dessication of the sand flats was common.

(D) Shale-sandstone lithofacies

Description of lithofacies D: Sequences 5 to 32 m thick, composed of shales and interbedded shales and sandstones, comprise lithofacies D (Sections 2 to 6, Figure 11). Three associations occur.

The first association occurs in the southwest of the area and lies gradationally above rippled sandstones. It begins with interbedded shales and rippled and flat-bedded sandstones gradationally below a middle section of shale. The shale section is in turn intercalated with thin sheet sandstones below lithofacies B sandstone units.

The rippled sandstones resemble those of facies C, but they are more argillaceous and display starved ripples, lenticular beds and bioturbation. Ichnofossils (Plates 22 and 23) include structureless trails and burrows and 1-2 cm wide trails decorated by an asymmetrical V-shaped ornamentation resembling chevron trails (Frey and Howard, 1970; Howard, 1972) and **Crossopodia** (Hantzschel, 1975). Mudcracks also occur locally.

The shales of the first association are 1-5 m thick, gray colored and contain paper-thin dolomite laminae and thin beds of ferruginous siltstone. The sheet sandstone beds that are interbedded with the shales at the tops of the sequences are fine grained and 5-20 cm thick. They have sharp, locally fluted, bases and internally consist of a massive division with small mudchips, overlain, in general, by lamination and ripple cross-lamination. Parting lineations occur and soft sediment deformation is common.

The second association consists of gray and black shales with a variety of interbedded sandstones and has been mapped in two thick sequences northwest of the Snakes Bight Fault (Section 5 and 6, Figure 11). These strata are associated with the gray, crossbedded, fining upward, channel sandstones of lithofacies B. Mudcracks and plant rootlets are common in some of the gray shales but are lacking in others. The black shales appear to lack mudcracks and are rich in blade-like plant fragments.

Thin, planar-bedded, laminated siltstones and very fine sandstones, 1-6 cm thick, are interspersed in the shales. They become increasingly important close to the facies B channel sandstones, where they are sheet-like, graded deposits up to 30 cm thick, and locally 2 m thick. Mudcracked bases are common and sedimentary structures include lamination, cross-lamination and small isolated crossbeds. In contrast, sheet sands with flat, irregular to fluted bases are usually seen in association with shales lacking mudcracks.

The third association also consists of sequences of alternating shales and sheeted sandstones. They lie stratigraphically above the gray and black shale sequences toward the top of the type section and attain thicknesses of 5-24 m. Here, the association comprises sheet-like deposits of gray, arkosic and micaceous sandstones, up to 30 cm thick, that alternate with 5 - 30 cm beds of mudcracked, green shales. The medium to very fine grained sheet sandstones are normally graded. Internally they are planar stratified, laminated and ripple cross-laminated. Crossbedding (5-15 cm thick sets) is less common. Bases preserve mudcracks and the tops of some sandstone beds are red. They closely resemble some of the beds in the Spout Falls Formation.

Interpretation of lithofacies D: The shales and sandstones of the first association in lithofacies D were deposited in shallow nearshore to offshore settings in what is now the southwest of the area. Alternating shales and rippled and planar-bedded sandstones, containing trace fossils and locally mudcracks, may imply shallow sublittoral to shoreline deposition. Shales lacking subaerial features but displaying dolomite laminae and thin laminated siltstones overlie these shoreline deposits. They suggest that water level rose to establish a quiet offshore setting dominated by deposition from suspension. In contradistinction, the intercalated sheet sands point to a turbidite origin. Turbidity currents presumably reached the offshore environment ahead of the prograding deltas responsible for sandstones of lithofacies B.

In the northwest and locally above thick sandstone units in the southwest (Section 2, Figure 12), the gray shales of the second association contain abundant evidence of dessication and active growth of vegetation. This suggests delta-top floodplain environments consisting of swamps and local, shallow ephemeral lakes. Anoxygenic gray and black shales without mudcracks were deposited locally in more permanent lakes.

Sheet sandstones and planar-stratified sandstones periodically blanketed the floodplain muds as flood waters breached river channels. Sand sheets with turbidite-like structures were laid down in the lakes, whilst crevasse splay sand sheets inundated the exposed muddy floodplain.

The sequences of sheet sandstones in the third association of lithofacies D are intercalated with mudcracked, green shales and they are interpreted as the deposits of shallow, ephemeral streams. They compare in character and origin to deposits of lithofacies B of the Spout Falls Formation. The non-erosive bases, the sheet-like beds, the dominantly planar lamination and the thin internal stratification are all in common with ephemeral stream deposits (Frostick and Reid, 1977; Tunbridge, 1981a and b).

(E) Red sandstone and pebbly arkose lithofacies.

Description of lithofacies E: Facies E is recognized only on Codroy Island, Grand Daddy's Brook and in some outcrops in the hills east of Ryans Brook. It represents only a few percent of the total Friars Cove Formation. It is composed of green to red arkosic small-pebble conglomerates, grits and very coarse and coarse sandstones lying erosively upon and overlain by micaceous, fine grained, red sandstones (Plate 24; Figure 12A).

Structureless, green, very coarse sandstones are overlain erosively by structureless conglomerate and grit in the section illustrated from Codroy Island (Figure 12A). These rocks consist of well sorted, angular pebbles of fine and medium crystalline red granites, pink feldspar, granite gneiss, brown-red rhyolite, green argillite, white quartz and yellow weathering limonitic clasts. The conglomerates are overlain by more green, coarse sandstones that contain 2 cm layers of arkosic grit and heavy mineral laminae.

The associated red sandstones are planar laminated and thin bedded below the arkosic rocks. Above the arkosic rocks, they also include some ripple drift, crossbeds, plant rootlets and shale partings with mudcracks and rain prints.

Interpretation of lithofacies E: Although there is a contrast in composition, grain size and sedimentary structures in the two lithologies of the facies, both deposits are interpreted as ephemeral stream deposits produced by flash floods of different magnitudes.

Red, thick, fine grained, micaceous sandstones were probably the characteristic deposits of the area. They illustrate planar lamination and thin bedding, ripple drift and mudcracked shale partings. These features are characteristic of shallow, sandy, ephemeral streams produced by flashfloods of moderate magnitude (Williams, 1971; Picard and High, 1973; Frostick and Reid, 1977; Tunbridge, 1981a).

The coarse-grained arkoses however, are thick-bedded, generally structureless, and rest in scours. The structureless character suggests rapid deposition of highly concentrated sand and gravel flows by a number of flood pulses, each of which had sufficient energy to scour a channel which it later filled. Major, but rare, catastrophic flashfloods probably served to bring coarser sediment into the more distal parts of the ephemeral stream system (Baker, 1977; Frostick and Reid, 1977). The composition of the detritus suggests a source southeast of the Long Range fault.

(F) Carbonate lithofacies

Description of lithofacies F: This minor facies includes stromatolitic dolomites, sandy dolomites and limestones, and dolomitic or calcareous sandstones. Sandy carbonates occur mostly in the southeast of the subbasin where they are associated with rippled sandstones of lithofacies C and shales of lithofacies D. To the northwest of Snakes Bight, one occurrence of stromatolitic dolomite has been noted in the basal conglomerate-sandstone facies (Section K 152, Figure 9). Similar units are also found in a shale sequence higher in the Friars Cove Formation in an unnamed stream valley near Johnsons Gulch.

The stromatolitic dolomites occur with the sandy dolomites. They are yellow-weathering, simple structures that include small heads resembling algal biscuit structures (Gebelein, 1969), broad flat heads composed of smooth laminated mat (Plate 25) and SH-C and SH-V growth forms (Logan et al., 1964) up to 10 cm in height and 7 cm wide. Loose float blocks of edgewise breccia and stromatolite are found in Grand Daddy's Brook. The associated sandy dolomites enclose intraclasts derived from the stromatolites. They are massive or poorly stratified and occur interbedded with thinly-bedded, locally bioturbated, gray calcareous mudstones, 30 cm thick.

The sandy limestones occur as well-sorted, cross- or planar-laminated and ripple-marked deposits. They form beds 10-15 cm thick and contain lenses of massive gray micrite. The sandy limestones are composed of clean quartz sand grains, micrite-coated quartz sand grains (Plate 26), ooids (Plate 27) and intraclasts of spar, micrite, calcareous algae and stromatolite. Some intraclasts enclose two or more ooids (Plate 27) and show early cementation.

Intergranular porosity, now indicated by the abundance of clear, coarse spar cement, was initially high.

Interpretation of lithofacies F: The carbonate facies was deposited locally in shallow, marginal lacustrine settings and is comparable to many modern and ancient lacustrine carbonate deposits (Fannin, 1969; Donovan, 1975; Eugster and Hardie, 1975; Link and Osborne, 1978; Schafer and Stapf, 1978). Mudstones were deposited in quiet lagoons. Stromatolites and well-sorted, ripple-marked sandy carbonates formed in agitated shoal and shoreline areas. Laminated algal mats developed on mud flats which were dessicated and locally disintegrated to provide abundant intraclasts.

Carbonate is rare and apparently only dolomites are present northwest of the Snakes Bight fault. Both limestones and dolomites occur, however, in the southeast where the limestones are rich in ooids and intraclasts. This suggests that the limestones may have been formed in more open, agitated, near-shore waters, whilst the microcrystalline dolomites formed in restricted, possibly hyper-saline areas only centimetres deep (von der Borch, 1976; von der Borch and Shock, 1979).

(G) Well sorted, sandstone-siltstone lithofacies

Description of lithofacies G: To date, lithofacies G has only been recorded in the uppermost strata of the Friars Cove Formation in the southeast of the area where it is only a minor component. There it is composed of well sorted, buff weathering, gray or black colored, generally fine grained sandstones and siltstones associated with some gray shale and rare intraclastic dolomite beds (Figure 12B). The sandstones illustrate variable bed thicknesses, and shale partings are common. Internal structures include lamination, flat bedding, ripple-drift cross-lamination, crossbedding and convolution. The laminations are sorted by grain size; some are rich in heavy minerals and/or mica and many exhibit parting lineations. Mudclast-rich layers are common in the sandstones. Ripple marks also occur, covered by either smooth or mudcracked and rain-pitted shale drapes. Some 30 cm thick, laminated, silty mudstones displaying lenticular and wavy bedding (cf. Reineck and Wunderlich, 1968) are interbedded with the sandstones.

Intraformational breccias are composed of shale, dolomite and reddened limestone intraclasts set in a shale and carbonate matrix. The breccias form lenses and beds 5 to 30 cm thick. Some beds are overlain by red, mudcracked, thin-bedded siltstones and sandstones.

Interpretation of lithofacies G: The presence of intraformational dolomite breccias, rippled sandstones, well-sorted laminated sandstones and mudcracked horizons suggests that facies G was also deposited in a shallow-water, marginal lacustrine setting. Lake levels fluctuated frequently on local and regional scales as water rose or fell in response to storms, evaporation, river inflow and outflow, and the driving effects of onshore or offshore winds (Oomkens, 1970). The sandstones with good sorting, ripple marks and laminated bedding were deposited on sandflats and beaches during high water levels. Mudflats and carbonate flats, which were later dessicated, formed as water levels receded. Intraformational breccias were produced when the flats were reworked during the next high water stage. In some cases, however, the dessicated flats were overlain by red, fine alluvium as offlap continued.

Strikingly similar facies occur in the Triasic East Berlin Formation of Connecticut (Hubert et al., 1976), where laminated and rippled sandstones are interpreted to have formed as sands on the shores and beaches of lakes.

Paleocurrents in the Friars Cove Formation

Paleocurrent measurements of ripple marks, parting lineations, rib and furrow and a few crossbeds are shown in Figure 13.

On Codroy Island, the few crossbeds give a fan-shaped, northwestward distribution. Parting lineations in the same area also give a northwestward trend. In the Anguille Mountains, crossbeds give west and southwestward directions, whilst parting lineations trend north-south. Data is insufficient, however, to make valid conclusions.

Symmetrical ripple marks from the rippled sandstones of lithofacies C have a prominent east-southeast to southeast crest trend and asymmetrical ripples give a north-northeast paleoflow (see also Cote, 1964, pages 254-257). These ripple-generating currents were perpendicular to those of the crossbeds and parting lineations, perhaps reflecting a northeasterly prevailing wind direction.

Age and correlative deposits of the Friars Cove Formation

No paleontological data is available for the Friars Cove Formation. Samples processed for microspores failed to yield any flora (Cote, 1964; Barss, personal communication 1979). The formation was correlated with the Ainslie member/formation of Cape Breton (Cote, 1964; Baird and Cote, 1964; Belt, 1969).

Depositional environment of the Friars Cove Formation

The gray sedimentary rocks of the Friars Cove Formation were deposited dominantly in a fluvial-deltaic, shallow lacustrine setting as the final fill of the Snakes Bight lake.

A significant period of tectonic instability occurred during the development of the Friars Cove Formation and is evidenced by the nature of the basal conglomerate member, the presence of thick sandstones throughout the formation, the immature composition of the sediments (see Petrography of Siliciclastic Rocks of the Anguille Group), and the marked stratigraphic thickening both northeastward and from northwest to southeast across the Snakes Bight fault. Subsidence and uplift occurred along northeast trending faults. In particular, the Snakes Bight fault was an active growth fault along which the southeastern part of the subbasin subsided. Cambro-Ordovician platformal rocks, Taconic ophiolite massifs and underlying Precambrian crystalline rocks were uplifted to form an upland herein named the Humber Arm allochthon highlands. These highlands provided detritus to the subbasin for the first time from north of the subbasin. Granitic and silicic volcanic pebbles in conglomerates laid down in the central and southeastern parts of the Anguille Mountains seem to indicate synchronous uplift of Paleozoic volcanic and granitic rocks southeast of the Long Range fault. Uplift of these source areas maintained steep drainage gradients so that rivers swept large quantities of coarse sandy (initially conglomeratic) material into the basin. Little evidence is available to determine the climatic conditions. Dolomite laminae in the shales and the rare dolomitic and stromatolitic beds as well as sandstones that were deposited by ephemeral streams suggest a semiarid climate.

Sandy detritus, which dominates the first 180 m of the Friars Cove Formation, was probably deposited in deltas that inundated the margins of the shallow lake in which the gray shales were accumulating. Along the northwest side of the subbasin, stratified, often pebbly, sandstones were deposited in ephemeral streams at times of flash floods. These sediments built up a series of fan deltas (cf. Sneh, 1979; Wescott and Ethridge, 1980) adjacent to the Humber Arm Allochthon highlands and the highlands southeast of the Long Range fault. Processes and deposits on the subaerial portions of fan deltas are essentially similar to those on modern alluvial fans (Wescott and Ethridge, 1980). Sandy sheetflood and ephemeral-stream deposits would lie basinward of inner-fan debris flow or stream gravel deposits. The latter reached the axis of the subbasin only rarely. Their existence is supported, however, by the Cape Anguille conglomerates. Gravel deposits were funnelled along channels into a deeper-water zone of the lake during the initial stages of fan delta construction. Lithostratigraphically, this episode marks the base of the formation. Basal conglomerates and sandstones in the center of the subbasin have a provenance to the southeast and show characteristics of braided streams. Similiar lithofacies may also have occurred along the southeastern margin of the subbasin at this time.

The middle part of the Friars Cove Formation, in the area northwest of the Snakes Bight fault, is dominated by gray shales and sheet and channel sandstones. Mudcracked horizons, plant remains and the presence of thin overbank sheet sands suggest a flat lying, broad, delta floodplain spotted with ponds and small lakes. Sediment was supplied by overbank flooding and crevassing from distributary channels and is represented by the fining-upward, crossbedded sandstones of lithofacies B. Sequences of intercalated shales and sheet sands (see association 3 of lithofacies D) formed on a mud and sand flat that lay along the inner edge of the delta floodplain. In the type section area, these deposits generally overlie shales interpreted to have formed upon the delta floodplain (association 2 of lithofacies D). The repetitive bedding suggests the sands probably resulted from reworking of sandy alluvium, perhaps from an alluvial fan, by ephemeral sheetfloods. The sheetfloods were generated by flashfloods that flushed the sand onto the inner edge of the muddy delta plain. This is the process and environment suggested by Smoot (1978) for deposits of comparable interbedded shales and sheet sandstones in the Wilkins Peak Formation of the Green River Formation. Crossbedded and laminated sandstones, locally oxidized to a red color, overlie the delta plain shales and sand and mudflat deposits. Lack of fine, red, overbank deposits associated with these gray sandstones and their resemblance to the redbeds of the overlying Spout Falls Formation suggests they were deposited by sandy, braided streams. They carried sandy detritus from basin-margin alluvial fans southeastward onto the inner margin of the delta plain.

On Codroy Island, a 690 m thick, incomplete section of the Friars Cove Formation illustrates cyclothems in the lower 120 m. Each cyclothem begins with shales overlain by massive-bedded and thick crossbedded sandstones that are, in turn, superseded by ripple-marked sandstones. Their presence in the southeast of the subbasin suggests that, at various times, the lake was filled by fluvially dominated, sandy deltas (Galloway, 1975). Provenance and paleocurrent data indicate that the deltas were built out into the lake along its southeast margin. The cycles point to both constructional and destructional phases. Thick-bedded, massive sands were deposited by sediment-laden floods discharged from river mouths. These high density underflows (cf. Lambert, et al., 1976; Sturm and Matter, 1978) probably constructed a large lobate-shaped delta (Miall, 1979). Shale interbeds, some mudcracked, may show that sedimentation was shortlived and repetitive. This may have been caused by frequent redirection of distributary channels due to avulsion or crevassing, or by intermittent fluvial sedimentation that was primarily controlled by the semiarid climate in which the subbasin evolved. Large planar crossbeds associated with trough crossbedding suggest that sandy braided streams (Miall, 1978; Walker, 1979) were established upon the delta platform.

The destructive phase of the cycles occurred after delta abandonment when lake level was maintained or rose. At such times, the delta sands were reworked by wind-generated wave activity into beaches and rippled sand flats in interdistributary bays or over the delta top.

Calcareous mud, gray shales and minor carbonates were deposited offshore along shallow, interdistributary bays and agitated shorelines. The dolomitisation of the carbonate deposits is suggestive of high Mg-Ca ratios (Muller et al., 1972) and high evaporation rates (von der Borch and Shock, 1979) in the shallow lake waters. A limited, soft-bodied fauna frequented the zone between the rippled sandflats and the offshore shale.

Shallow-lacustrine to shoreline conditions were maintained in the southwest of the subbasin into the late stages of development of the Friars Cove Formation. The generally gray rocks formed in these environments underlie basal strata of the Codroy Group as far north as the "round valley" and the North Branch of the Grand Codroy River. Here, however, a transition occurs northwards into sandy, red alluvium of the Spout Falls Formation. It appears that south of this transition braided streams that carried coarse pebbly to sandy detritus from the southeast margin into the axial zone of the subbasin caused the lake to shrink appreciably in size at times.

Spout Falls Formation

Definition and distribution

A complex of geographically separated rock sequences are here grouped together in the Spout Falls Formation. They include:

(1) Red and gray sandstones with minor siltstones and conglomerates that underlie the northern half of Anguille Mountains, Bald Mountain and continue northeast adjacent to the Long Range Fault almost to Barachois Brook. They are equivalent to the upper red sequence of the Seacliffs Formation of Baird and Cote (1964).

(2) Gray and minor red conglomerates and sandstones called the Fischells conglomerate member (Baird, 1951). This forms the core of the Flat Bay anticline and occurs faulted against the Steel Mountain anorthosite massif along Sheep, Coal and Flat Bay Brooks. Belt (1969) called it the Fischells Brook Formation. A thin (1-2 m) conglomerate that lies beneath basal Codroy Group limestone (Windsor subzone A, von Bitter and Plint-Geberl, 1982) on the Port au Port Peninsula and at Romaines Brook at the northern margin of the subbasin is included in the Fischells conglomerate member.

(3) Basal strata of a thick sequence of fault-bounded, red arkosic rocks informally defined by Fong (1976) as the Brow Pond lentil may also be time equivalent to strata of the Spout Falls Formation. The basal strata are tilted, gently folded and overlain unconformably by arkosic rocks comprising the rest of the lentil.

The top of the Spout Falls Formation is placed throughout the subbasin at the base of the Ship Cove Formation.

Thickness

The Spout Falls Formation forms a northeastward thickening prism of sediment. South of the "round valley", Codroy lowlands, Spout Falls lithologies are seen as thin intercalations within the strata of the Friars Cove Formation. They are not separable on the scale of the accompanying map. The formation is 780 m thick northwest of the Snakes Bight Fault but it is calculated from structural cross sections to thicken to at least 2250 m just west of Codroy Pond at the north end of the Anguille Mountains. This marked thickening is attributed to active, fault-controlled, syndepositional subsidence. This notion is further supported by the thickening of Friars Cove Formation across the same Snakes Bight fault.

The Fischells conglomerate member is estimated to be 100 to 150 m thick (Fong, 1976; Fong, personal communication, 1976) in the Flat Bay anticline and at least 200 m thick along Coal Brook (Baird, 1949).

General lithology

The Spout Falls Formation in the Anguille Mountains and Bald Mountain consists of well indurated to friable, red, reddish-gray, gray and green calcareous, arkosic and micaceous sandstones. Conglomerates, intraformational conglomerates and minor siltstones and shales also occur.

The succession is dominated by fluviatile sandstones exhibiting abundant scouring, and a well-bedded, sheet-like geometry (Plate 28). Mudchips, intraformational conglomerates, abundant parallel stratification and lesser quantities of crossbedding are present. Siltstones are uncommon and conglomerates are sporadically distributed. The 250 m thick incomplete section at Friars Cove delineates no fining- or coarsening-upward grain size trends. However, Cote (1964) measured a generalized, incomplete section of 500 m on Lewis Gulch which shows the upper 250 m to be slightly more granular and pebbly than the lower part of the section.

As the Spout Falls Formation is traced northeastward, lenses and thin beds of conglomerate become more abundant, particularly adjacent to the Long Range fault northeast of Bald Mountain. Rounded to subangular pebbles consist overall of red granite which may be porphyritic, gray granite gneiss, porphyritic and aphanitic brown and green silicic volcanics, white quartz, white quartzite and limestone. Quartzite and limestone clasts are noticably absent, however, in exposures on Bald Mountain. Pebbles only 8 mm in maximum dimension occur in the Friars Cove section but they increase in size to 12 cm in diameter farther northeast at Lewis Gulch and around the northern closure of the Anguille anticline.

The Fischells conglomerate member is composed of gray and red, well indurated, polymictic conglomerate and lenses of sandstone. An approximately 20 m thick unit of flaggy, gray sandstones occurs in the middle of the member on the east side of the anticline on Fischells

Brook (D. Rogers, personal communication, 1981). The member consists of gray strata in the north of the Flat Bay anticline but gray beds are intercalated with red sandstones in the south near Robinsons River. Gray conglomerates extend as far south as the Highlands River where they are interbedded within gray and red sandstones near the northern closure of the Anguille anticline (Fong, personal communication, 1976). Red and gray beds occur in the member near the Steel Mountain anorthosite (Baird, 1949).

The conglomerates of the Fischells conglomerate member consist of rounded and subrounded pebbles and cobbles near Steel Mountain, and pebbles in the Flat Bay anticline. The clasts in the latter locality were mostly derived from the erosion of Cambro-Ordovician carbonate rocks supplemented by white quartz, red jasper, granite, silicic volcanic and metamorphic clasts shed from the central Newfoundland uplands. Near Steel Mountain, they consist of vein quartz, white, buff and reddish quartzites, several granitic rock types, diabase, some basic plutonic lithoclasts, gray, commonly cherty limestone and red shale (Baird, 1949).

Six lithofacies have been delineated in the Spout Falls Formation. Some are observable in the section at Friars Cove. They are (A) thick-bedded sandstone lithofacies, (B) stratified sandstone lithofacies, (C) fining-upward sandstone-siltstone lithofacies, (D) sandstones with large-scale crossbeds (E) siltstone - very fine sandstone lithofacies and (F) conglomerate lithofacies.

(A) Thick-bedded sandstone lithofacies

Description of lithofacies A: Lithofacies A consists of red, gray and green sandstones, pebbly sandstones, minor conglomerate, intraformational conglomerate, thin shaly siltstones and shales in sequences up to 10 m thick. It comprises some 41% of the incomplete section measured on Friars Cove and is characterized by beds, 20-60 cm and locally 2 m thick, of medium to very coarse grained sandstone. The beds have a sheet-like geometry, vary in thickness along the bed and may be separated by thin siltstones or shale partings (Sections 1, 2, 3, Figure 14).

Sandstone beds within this lithofacies begin with planar, broadly curved or irregular scours which are overlain by one or more of the following: (1) small pebble conglomerates or intraformational conglomerates with clasts locally concentrated in the scour depression; (2) well to poorly defined, horizontal to slightly inclined stratification with some solitary crossbeds; (3) structureless beds of sandstone or pebbly sandstone (Section 1, 2, Figure 14); (4) planar cross-stratification which may also overlie a basal conglomerate; and (5) trough crossbeds overlain by some laminated and cross-laminated rocks. Grain size and sedimentary structure size decrease upwards in some sequences where planar crossbeds are overlain by trough crossbedded and/or laminated horizons. Trough crossbeds, which locally contain convoluted foresets, are 10 to 25 cm thick, and 10 to 200 cm in length. Isolated cross-sets in laminated beds have broad shallow scours, 1.5 to 2 m wide and 10 to 20 cm deep. They are filled concordantly by stratification similar to the Zeta or Theta cross-stratification of Allen (1963). Ripple marks occur on the tops of some beds.

Shaly siltstone and shale beds up to 15 cm thick are interbedded with the sandstones. In many cases, however, shale partings and drapes separate the sandstone beds. The shales are commonly mudcracked.

Interpretation of lithofacies A: The characteristics of lithofacies A suggest deposition in shallow, sandy braided streams. Separation of sandstones by mudcracked layers of shale and siltstone may indicate that each sandstone bed represents a distinct depositional event. This further implies that the braided fluvial system either was ephemeral or was characterized by rapid lateral shifting of channels.

The erosional bases, abundant mudclasts and sheet-like geometry of the sandstones support an interpretation based on frequent lateral shifting of channels and erosion of previously deposited units. Deposition within channels was variable. Horizontal and low-angle planar, crude stratification was perhaps formed in longitudinal bars (Smith, 1970). Such stratification likely represents plane beds produced by currents with velocities characteristic of the upper flow regime (Simons et al., 1965; Southard, 1975). Planar cross-stratification formed within transverse or linguoid bars (Williams, 1966, 1971; Collinson, 1970a; Smith, 1972). Trough crossbeds formed within megaripples (Harms, 1975; Cant and Walker, 1978; Walker, 1979a) that migrated along channels or over channel bars as described for ephemeral and large perennial, braided river channels (Williams, 1967, 1971; Collinson, 1970a; Karcz, 1972; Cant and Walker, 1978). Fining-upward units illustrating the change from planar stratification to crossbedding and cross lamination or lamination without parting lineations (lower plane bed, Harms, 1975) indicates that deposition was caused, in some instances, by gradually waning currents.

(B) Stratified sandstone lithofacies

Description of lithofacies B: Gray, arkosic and micaceous sandstones, 5 m thick, (Section 3, Figure 14) and units of gray sandstone grading to red sandstone, 2-4 m thick (Section 4, Figure 14) comprise this lithofacies. The fine grained sandstones are mostly ungraded but some units fine upward. Lithofacies B composes 51% of the section measured °in Friars Cove.

The facies generally displays a characteristic, 1-4 cm spaced planar stratification cross-cut at 30 to 60 cm intervals by broad, planar scours. Parting lineations are most common in the lower parts of the sequence but not in the upper, finer grained, red sandstones. Ripple cross-lamination and convolute bedding also occur and some bedding planes are blackened by fine plant trash. Pea-size mudclasts occur above some of the scours.

A slightly different sequence is illustrated in Plate 29. Here a basal scour is overlain by more than 2 m of stratified sandstone without internal scours. The deposit is capped abruptly by red siltstone.

Interpretation of lithofacies B: Lithofacies B is characterized by thick sequences of planar-stratified and laminated sandstones rich in parting lineations. These stream deposits formed in the upper flow regime (Allen, 1964b; Simons et al., 1965; Southard, 1975); the stratification may have formed over a wide range of flow velocities because of the generally uniform, fine grain size (Simons et al., 1965).

The regular development of scours and the general lack of lower flow regime structures suggests that the deposits were mostly built up by a repetitive fluvial process. It involved high flow energy and rapid current deceleration, so that erosion was followed mostly by the production of sedimentary structures of the upper flow regime. Such properties are characteristic of flashflood-generated, ephemeral streams in areas of semiarid climate (McKee et al., 1967; Williams, 1971; Picard and High, 1973; Frostick and Reid, 1977; Tunbridge, 1981a and b). They are untypical of perennial meandering or sandy braided systems which controlled the deposition of the intercalated rocks of lithofacies A (Allen, 1964a, 1965a, 1965b; Smith, 1970; Cant and Walker, 1976; Miall, 1977; Walker, 1979a).

Thick facies B sandstones that lack internal scouring, overlie a sharp, erosive base and are capped abruptly by red siltstone, may be channel fills produced by stream flow in a single major flood. The channels were rapidly abandoned and hence channel fill was abruptly overlain by a siltstone layer deposited by vertical accretion.

(C) Fining upward, sandstone-siltstone lithofacies

Description of lithofacies C: Lithofacies C is formed of gray to red, coarse or medium, often pebbly, sandstones grading up into very fine red sandstone and siltstones. The sequences, which are 3.5 to rarely 15 m thick, are not very common. Irregular, 1 m deep, channel scours are locally associated with intraformational mudchip or pebble conglomerate and some plant debris. Sedimentary structures in overlying coarser sandstones include trough crossbedding and planar lamination (Section 1, Figure 14); minor ripple cross-lamination may also occur. Crossbeds vary in thickness from 10 to 25 cm with sets up to 200 cm wide.

Very fine, often micaceous red sandstones and siltstones form the top beds of facies C sequences. Wavy lamination, thin bedding, ripple drift, plant rootlets and thin lenticular layers of red siltstone occur in the sandstones. Siltstone beds are 1-3 m thick. They are bright red and structureless except for some faint lamination, waxy shale partings and some thin green layers. Plant rootlets, mudcracks and some small calcareous nodules (caliche) occur in some of the siltstones.

Interpretation of lithofacies C: The trough crossbedded and planar-laminated, fining-upward sandstones of lithofacies C that overlie basal scours with an intraformational or pebble lag, are here interpreted as channel-fill deposits. Irregular basal scour and abundant mudclasts at the base of infills are distinguishing features of channel floor and lag deposits commonly found at the base of fluvial sequences (Allen, 1965a, 1965b; Walker, 1979a). Such deposits are suggestive of active bank erosion and lateral migration of channels. Trough crossbedding overlain in some units by planar lamination may imply the presence of in-channel megaripples (dunes) and upper flow regime plane beds (Harms, 1975). These structures, as well as ripple cross-lamination and an upward grain size reduction, generally indicate a waning current flow. Thick siltstones gradationally overlying the channel sandstones suggest channel abandonment with infill by fine, vertical-accretion deposits.

The general character of the sandstone bodies bears some resemblence to that ascribed to sandstone deposits of meandering streams (Allen, 1965a; Walker, 1979). Nonetheless, the association of the facies with strata deposited mostly by shallow braided and ephemeral streams possibly suggests that lithofacies C sandstones were deposited in low-sinuosity stream channels.

(D) Sandstones with large-scale crossbeds.

Description of lithofacies D: Sandstones composed of very large scale, high-angle, planar crossbeds at least 5° m in thickness were noted only once in the Spout Falls Formation and that was in a cliff on Lewis Gulch (Plate 30). The crossbeds, with an apparent east-northeast dip, lie against the side of a large, elliptical scour which cuts deeply into the underlying strata. The large crossbeds are themselves truncated by a planar scour which is overlain by planar and trough crossbeds.

Interpretation of lithofacies D: Large crossbeds of the scale of those seen in Lewis Gulch are known to form in association with deep channels as: (1) alternate bars attached to channel margins (McCabe, 1977); (2) large sand waves within river channels similar to those described by Conaghan and Jones (1975) and Coleman (1969); or (3) a s delta-like deposits infilling abandoned river channels or forming at the confluence of two deep channels (McCabe, 1977).

An alternate-bar model is favoured here because the large crossbeds are attached to one margin of a large channel. Smaller scale crossbeds overlying the large sets are probably similar to the medium scale crossbeds formed by migrating megaripples. Such deposits are reported to overlie the alternate bars of deep channels in the Upper Carboniferous of Yorkshire (McCabe, 1977).

(E) Siltstone - very fine sandstone lithofacies

Description of lithofacies E: Red and gray siltstone and very fine sandstone form uncommon (less than 2% of measured section, Friars Cove) but distinct units, 10-80 cm thick in strata dominantly composed of lithofacies A and B (section 2, Figure 14). Beds within facies E units are 5 to 20 cm thick. Planar and wavy lamination, ripple drift, mudcracks and plant rootlets are common structures.

Interpretation of lithofacies E: Grain size and sedimentary structures suggest that the sandstones and siltstones were deposited by slow, shallow currents in standing water bodies. They resemble facies Fl of Miall (1977) and facies a and b of the Donjek River (Williams and Rust, 1969) which were deposited in shallow pools, abandoned channels, or marginal areas in a braided river system. Mudcracked horizons suggest the pools and channels were frequently dessicated.

(F) Conglomerate lithofacies

Description of lithofacies F: Lithofacies F is found in the Fischells conglomerate member. It consists of conglomerate beds, several metres thick, and some sandstone. The conglomerates have erosional bases and are mostly internally massive. Crude horizontal stratification is visible where long axes of pebbles lie parallel to bedding; some pebbly crossbeds also occur. Sandstones in beds and lenses mostly up to 2 m thick are generally planar stratified or crossbedded; they locally infill irregular depressions in the tops of conglomerate beds.

Interpretation of lithofacies F: The conglomerates with lenticular sandstones are probably deposits of gravelly braided streams (Rust, 1972; Miall, 1977). Erosive bases overlain by thick conglomerate units with lenticular sandstones imply shifting and fluctuating flow conditions. The massive to stratified conglomerates were deposited in longitudinal bars and the crossbedded deposits were likely laid down in transverse bars (McDonald and Banerjee, 1971; Smith, 1974).

<u>Paleocurrents in the Spout Falls Formation</u>

Only a few current directions were collected, most of which are parting lineations and other small scale structures. They give a generally southerly direction of transport for the sandy facies in the Anguille Mountains. Southeasterly paleoflow occurs at Friars Cove but in the central area of the Anguille Mountains there is a southerly to southwesterly paleoflow.

Age and correlative deposits of the Spout Falls Formation

Similar redbed sequences are found near the top of the Horton Group throughout much of the Maritimes Basin where they underlie the basal limestones of the Windsor Group. The latter are equivalent to the Ship Cove limestone of the Codroy Group. The Spout Falls Formation is correlated with the Cheverie Formation (Bell, 1960) of Nova Scotia. Cote (1964) correlated it with the Ainslie Member of the Ainslie - Strathlorne Formation (Kelley, 1967a) of Cape Breton. Redbeds of the Weldon and Hillsborough Formations in New Brunswick (Gussow, 1953; Greiner, 1962) (see Table 2) are thought to straddle the time period of the upper Horton Group and lower Windsor Group.

Belt (1969; personal communication, 1981) has suggested that the Fischells conglomerate member is Windsorian in age. However, this is based upon spores identified in shales at the base of the overlying Ship Cove Formation which are clearly not part of the conglomerate sequence.

Depositional environment of the Spout Falls Formation

The dominantly red strata of the Spout Falls Formation were deposited in a sandy and gravelly fluviatile environment that prograded southward over the lacustrine-deltaic sediments of the Friars Cove Formation. By the end of Anguille deposition, the redbeds filled the subbasin as far south as the "round valley" and, for brief intervals, blanketed the subbasin in the southwest (e.g. lithofacies E of the Friars Cove Formation).

The Spout Falls Formation is dominated by a thick succession of red fluvial sandstones that accumulated in the axial region of the subbasin. It is characterised by deposits of shallow, sandy, braided and ephemeral streams (lithofacies A & B). The unique sheet-like geometry of the succession compares closely to the braided-sheet, fluvial style of Cotter (1978). He interprets such rocks to be indicative of the vegetation-free environments of semiarid areas. The importance of planar stratification in the sheet sandstones suggest that ephemeral sheetflood and channelwash dominated the fluvial environment. Flashfloods, which are very typical of semiarid climatic areas (Cooke and Warren, 1973; Frostick and Reid, 1977), controlled these deposits. Sediment was then reworked downslope from basin margins towards the basin axis to form a sandy flood plain. Tectonic instability and rapid subsidence in the subbasin maintained steep, stream gradients. These gradients allowed strong currents to sweep fines through the flood plain and contributed to the general lack of overbank siltstones in the formation. Nevertheless, some fining-upward channel sandstones, capped by overbank red siltstones (lithofacies C), suggest that low-sinuosity streams did cross the flood plain at times. Sandstones with large-scale crossbedding (lithofacies D) also support the presence of some large river channels within the subbasin. The deposits interpreted as alternate bars are similar to strata displaying epsilon cross-stratification (Allen, 1963). Leeder (1973) used this type of stratification to define channel depth. It appears that these crossbeds in the Spout Falls sandstones formed in a channel with a depth greater than 5 m and a width of possibly hundreds of metres (cf. McCabe, 1977). A channel of this magnitude indicates the presence of a large perennial river. It probably supplied the sandy, fluvially dominated deltas of the Friars Cove Formation to the south. The paucity of overbank fines in the succession most likely means that the river was entrenched in its sandy flood plain and was perhaps internally braided. (cf. Coleman, 1969; Collinson, 1970a; Cant and Walker, 1978).

Alluvial fans composed of sands and gravels were likely deposited along the edges of the subbasin although little data is available from the Spout Falls Formation in these areas. Increasing pebble content together with the composition of sands and pebbles near the Long Range fault support the idea of a build-up of alluvial fans along the primordial structure. Basal arkoses of the Brow Pond lentil may have been deposited as a coarse, sandy, alluvial fan at approximately the same time in the northeast corner of the subbasin. South to southeastward paleocurrents as well as pebbles of Lower Paleozoic platformal rocks from northwest of the Snakes Bight fault seem to indicate that similar sandy and gravelly fans developed along the southeastern margin of the Humber Arm allochthon highlands.

Active subsidence in the subbasin during Spout Falls deposition was centred at the north end of the Anguille anticline, southeast of the Snakes Bight fault. The absence of a lacustrine facies in this area suggests that substantial sediment accumulation was maintained by the sandy, braided, fluvial system. It also implies steady resedimentation of alluvium from the marginal alluvial fans to the axis of the subbasin. High sedimentation rates prevented the formation of meandering rivers.

Caliche is notable by its general absence in a succession thought to have been deposited in a semiarid climate. This feature, however, probably reflects the high sedimentation rate (Leeder, 1975). The commonly observed calcareous cement of the Spout Falls sandstones is, however, known to form rapidly in semiarid climatic regions particulary in sands that are deposited near limestone uplands (Glennie, 1970; see also Frostick and Reid, 1977, page 2). A semi-arid climate is evidenced by (a) lack of vegetation, (b) sheeted, ephemeral stream deposits dominated by planar stratification (Frostick and Reid, 1977; Cotter, 1978; Tunbridge, 1981a), (c) fresh detrital grains (Folk, 1968) and (d) ferruginous impregnation and coating of detrital grains (Walker, T.R., 1963, 1967a and b; Glennie, 1970; Cooke and Warren, 1973).

The conglomerates of the Fischells conglomerate member are interpreted as gravelly, alluvial fans. They were deposited in close proximity to their source, the Humber Arm allochthon highlands. The gravel fan was formed late in the depositional history of the Spout

Falls Formation, probably apart from the hypothetical, alluvial fan deposits that were reworked to form the thick, sandy, axial, basin-fill succession. The Fischells conglomerate member may not be laterally persistent. It is most likely a local deposit restricted to the area of the Flat Bay anticline; that it extended along the entire northwest margin of the subbasin is improbable.

Precambrian crystalline rocks that appear to underlie much of St. George's Bay area (McKillop, 1959; Spector, 1969; Golden Eagle Developments Ltd., 1975) are overlain by the Codroy Group. Here any sub-Codroy strata are anticipated to be similar to the conglomeratic facies of the Fischells conglomerate member. Such conglomerates, however, appear to thin northward from Flat Bay (150 m) to Romaines Brook (2 m) at the northern edge of the basin, and may be absent under much of the bay.

Evidence that the Fischells conglomerates formed contemporaneously with the upper part of the Spout Falls Formation is not conclusive. This concept is supported, however, by gray pebble beds intertonguing with Spout Falls sandstones at the northern closure of the Anguille anticline, and red sandstones in the conglomerates at the southern end of the Flat Bay anticline (Fong, personal communication, 1976). The thick wedge of flaggy sandstones intercalated with the conglomerates on the east limb of the anticline also suggest a rapid southeastward transition from the conglomerates into sandstones. This might imply that the conglomerate member formed a narrow, gravel bajada along the northwest, fault-bounded margin of the subbasin for some time.

Petrography of the Siliciclastics of the Anguille Group

The sandstones of the Anguille Group include lithic arkoses, arkoses, subarkoses and sublitharenites (Folk, 1968). Examination of more than thirty thin sections revealed that detrital components are consistent from one formation to another, although variations occur from place to place within the same formation. The sandstones contain abundant perthite and microcline grains in association with fragments from high-level granitic intrusions that have graphic and granophyric textures. Grains of silicic volcanics and low grade metamorphic rocks are also common.

In general, the sandstones are moderately well sorted to poorly sorted (Beard and Weyl, 1973). They are well sorted in ripple bedded, calcareous sandstones of the Friars Cove Formation and some of the red sandstones of the Spout Falls Formation. Grains in general are angular to subrounded so that feldspars retain prismatic shapes with only rounded corners; heavy minerals are prismatic or irregular in shape. Grains show better rounding in well sorted, rippled sandstones of the Friars Cove Formation.

Matrix and cement variably fill intergranular space in the sandstones. Grain contacts, suturing and annealing are common and quartz overgrowths occur. Fine, felted chlorite comprises the matrix of the Kennels Brook sandstones and some sandstones of the Snakes Bight and Friars Cove Formations. It is most common, however, to find the Anguille Group sandstones cemented by carbonate and locally silica. Etching of quartz grains by carbonate is variable and preferential replacement of feldspars by carbonate cement occurs along cleavage planes, in perthitic phases or around grain edges. Pyrite and limonite are common in the gray sandstones; hematite and limonite coat sand grains in redbeds of the Spout Falls Formation.

Single and composite quartz grains are present in the Anguille Group sandstones. Single grains include both unstrained and variably strained quartz. The latter shows undulose extinction, deformation lamellae and slight recrystallization. Vacuoles, vacuole trails, rutile needles, small muscovite plates, some apatite and less tourmaline occur within quartz grains. Some quartz grains in the Friars Cove Formation in the southwestern outcrops of the group are clear. They lack vacuoles and some grains have embayed boundaries. These characteristics may indicate that such clear grains were once quartz phenocrysts in subvolcanic granites or silicic volcanics. 'Common' composite quartz (Folk, 1968) of vein and plutonic origin is otherwise ubiquitous. Composite grains of metamorphic origin include very anisotropic grains with extreme crystal elongation and smooth crystal contacts suggesting mylonitic quartz, stretched quartz with sutured crystal contacts, schistose quartz with small oriented muscovite flakes and granoblastic quartz.

Microcline and perthite are abundant in the sandstones with variable quantities of plagioclase and orthoclase. Plagioclase, which appears to be mostly oligoclase, is as abundant as K-feldspar in parts of the Kennels Brook and Snakes Bight Formations. It was rarely encountered in sectioned sandstones from the Spout Falls Formation. Microcline and perthite dominate in the Friars Cove Formation. Feldspars are fresh to altered, with varying degrees of sericitization and vacuolisation common. Vacuolisation affected alkali feldspars, particularly in sandstones of the Friars Cove Formation on Codroy Island. **In situ** degradation of feldspars was not noted.

Large plates and flakes of muscovite, biotite and chlorite occur in the sandstones. Muscovite and chlorite are most common but these micas rarely form more than a few percent of the sandstones and, in some Friars Cove rocks, they are absent. Biotite is the least common mica. Green biotite was, however, noted in Friars Cove sandstones from Codroy Island, in the Spout Falls Formation in the north of the Anguille Mountains and in sandstones of the Fischells conglomerate member along Fischells Brook. Iron oxides generally impregnate or speckle muscovite and biotite, and radioactive haloes were noted in some khaki-colored biotites.

Plutonic rock fragments consist of quartz-plagioclase or quartz-alkali feldspar ± micas. Although they are common in the coarser sandstones, they are absent in thin sections of Kennels Brook sandstones. Mafic and silicic volcanic rock fragments may be important or absent. Mafic clasts usually consist of plagioclase microlites set in a chloritized groundmass speckled by iron oxides; some contain larger lath-shaped plagioclase crystals. Felsic volcanic grains display spherulitic, felted, feathery and indistinct devitrification textures. Porphyritic cherts and quartz-feldspar porphyrys also occur.

The latter are particularly prominent in pebbly arkoses of the Friars Cove Formation, Codroy Island, where they are associated with fresh reddened microclines.

Apart from phyllites, chlorite schists and quartz-sericite or muscovite schists, metamorphic grains are rare. Some metachert resembling deformed silicic volcanics of the Windsor Point Group (Chorlton, personal communication, 1981) and metaquartzite grains occur. Sedimentary grains include uni- or poly-crystalline calcite, siltstone and very fine sandstone and some chert.

Zircon and tourmaline in large and small grains dominate the heavy mineral suite. Zoned, twinned and prismatic, green, yellow and brown tourmalines occur. Garnet, epidote, rare brown hornblende, rare sphene and possible red rutile were also noted. Magnetite, hematite and leucoxene are scattered in the sandstones or are locally concentrated in laminae in rippled sandstones of the Friars Cove Formation.

Age and Correlative Deposits of the Anguille Group

The upper part of the Anguille Group is of Lower Mississippian age (Baird and Cote, 1964). The group can be correlated with the Horton Group of Nova Scotia (Hayes and Johnson, 1938; Bell, 1948; Baird and Cote, 1964) which is Famennian to Tournaisian in age (Playford, 1963; Hacquebard, 1972). The lithostratigraphy of the Hortonian rocks of Maritime Canada is summarized in Table 2. In Newfoundland, sedimentary rocks of Tournaisian age are also assigned to the Anguille Group in the Deer Lake Basin (Hyde, 1978, 1979a, 1979b; Hyde and Ware, 1980, 1981).

Miospores and plant fossils from the Anguille Group are rare and badly preserved (Cote, 1964; Barss, personal communication, 1979). Only one sample out of thirty-five processed for spores (Cote, 1964) yielded a spore assemblage. No spores were found in several samples collected by the author (Barss, personal communications, 1979). Cote's one sample collected from a location on the north shore of Snakes Bight in the Cape John Formation (Cote, 1964) yielded an assemblage apparently slightly older than those of the Craignish Formations of Cape Breton (see Table 2) and the Horton type sections of Bell (1960) in Nova Scotia. The location of this sample is uncertain and in light of a structural reinterpretation of this particular area, the sample may belong to the uppermost Spout Falls Formation rather than the basal Kennels Brook Formation, suggesting that much of the Anguille Group is Devonian. Bell (1948, page 5) identified several plant fragments from the Anguille Group and concluded they suggested an age equivalent to the upper part of the Horton Group.

Although a Tournaisian age is generally accepted for much of the Horton Group, opinions vary as to its time duration. Hacquebard (1972) suggested that the group extended throughout the Tournaisian. Geldsetzer (1978), however, speculated that Horton sedimentation was confined to the lower part of the Tournaisian. For the Maritimes Basin, this implies a depositional hiatus of several million years after the accumulation of the Horton Group. The possible hiatus would have lasted till at least the middle Visean (Mamet, 1970) when the sediments of the overlying Codroy and Windsor Groups were deposited.

Summary and Geological History of the Anguille Group

The geological data presented above show that the Anguille Group consists of a sequence of nonmarine fluviatile and lacustrine strata laid down in a generally narrow, tectonically active basin. Sedimentation within the Bay St. George subbasin at this time reflects the infill of a fairly deep, elongate lake, following dominantly fluvial sedimentation in the late Devonian, as summarized in Table 3.

The Kennels Brook Formation consists of fluvial redbeds and some lacustrine strata that were probably deposited during the late Devonian. This formation, which is more than 3200 m thick beneath the Anguille Mountains, is unknown elsewhere in western Newfoundland. It probably represents a pre-Horton/Anguille phase of sedimentation.

Redbeds of the Kennels Brook Formation may have formed part of an extensive molasse blanket. This post-Acadian molasse would have extended westward out into the Gulf of St. Lawrence area (Haworth and Sanford, 1976) from source mountains southeast of the Long Range Fault. Erosion of much of this blanket may have occurred, prior to Codroy Group deposition, when the Humber Arm allochthon highlands formed northwest of the subbasin. Alternatively, the redbeds may have been locally developed as a thick basin-fill sequence confined to a fault graben.

If thick, nonmarine Devonian molasse did flood a successor basin west of the Acadian fold belt, it is possible that sedimentation began as early as the Early Devonian when the Clam Bank Formation (Rodgers, 1965; O'Brien, 1975) was deposited. This formation, which is tilted steeply westward in fault contact with Cambro-Ordovician platformal rocks, occurs at the western edge of the Port au Port Peninsula. It contains no carbonate detritus, yet has westerly directed paleocurrents (H. Williams, personal communication, 1978). The Lower Devonian redbeds might have buried large parts of the Cambro-Ordovician platform.

The substantial thickness of the Kennels Brook Formation is in keeping with the notion that molasse sedimentation could have been maintained in western Newfoundland throughout the Devonian. Tectonic activity leading to uplift, sedimentation, volcanism and deformation also occurred during the Devonian particularly along the Cape Ray fault system (Brown, 1977; Chorlton and Dingwall, 1981; Kean and Jayasinghe, 1981). Compressive stresses were probably released along major faults so that variably sized successor basins were widely distributed in depressions and along faults in and peripheral to the Acadian fold belt.

A major cycle of sedimentation that includes the remaining three formations of the Anguille Group followed the Devonian molasse sequence. It records the history of formation and infill of a lacustrine basin.

An inland drainage basin was formed in which lacustrine conditions were rapidly established as the basin was supplied by rivers draining from central Newfoundland and uplands to the north. The lake was relatively steep-sided and possibly up to 100 m deep at its maximum development. It was initially filled by a deep water lacustrine sequence, the Snakes Bight Formation, that was deposited over a period of at least 300,000 years. Turbidites were deposited in the lake, possibly on sublacustrine fans in front of steep-fronted deltas. Quiet-water, basinal muds typical of a stratified, meromictic lake were laid down extensively in the lake. This lake shallowed at an accelerating rate as sandy deltas encroached along the basin margins and axis. As the lake became infilled, sand-dominated deltas built an extensive plain on which marsh, shallow lacustrine and fluvial subenvironments flourished during the deposition of the Friars Cove Formation. Deltaic and shallow lacustrine conditions persisted in the southwest of the basin until the end of deposition of the Anguille Group. However, fluvial sedimentation predominated to the north and northeast where gray sandstones of the Friars Cove Formation were initially laid down but then gave way upward into redbeds. The latter, which comprise the Spout Falls Formation, were deposited widely in the north-central area of the subbasin by shallow ephemeral and braided streams that constructed a sandy, alluvial plain. Large rivers also crossed the alluvial plain at times to and supplied the contemporary lacustrine deltas to the southwest.

Sandy and gravelly alluvial fans were laid down around the edges of the subbasin. The Fischells conglomerate member in the Flat Bay anticline may have formed as a local fanglomerate in the north of the subbasin. Less likely, they were part of a narrow zone of fanglomerates that may have periodically marked the northwest margin of the subbasin during Anguille Group time. Detritus was derived from the Humber Arm allochthon highlands.

Although sedimentological evidence is not conclusive, dolomites in the shallow and deep lacustrine sequences, and redbeds deposited by ephemeral streams suggest that the climate was at least semiarid during the evolution of the Anguille Group. Several paleomagnetic studies independently verify that the Maritime provinces were 10° to 20° south of the palaeo-equator during the Devonian and Carboniferous (Roy, 1973; Smith et al., 1973; Irving, 1977).

General points of interest in summarizing the paleogeography of the group are: (1) that the thick siliciclastic succession was supplied predominantly with detritus from southeast of the Long Range fault throughout the deposition of the basin fill; (2) evidence for a detrital source north of the subbasin in the Cambro-Ordovician platformal and allochthonous rocks of western Newfoundland is present only in siliciclastics of the Friars Cove and Spout Falls Formations; (3) the subbasin was probably narrow and elongate. If the present distribution of rock units reflects closely their original distribution, a subbasin no more than 30 km wide and 100 km long seems probable; (4) the shape and form of the subbasin was largely controlled by northeast trending faults. These structures included the primordial Long Range fault along the southeast margin of the subbasin, the primordial Snakes Bight fault within the subbasin, and an unnamed fault that formed the northwest margin and is now believed to lie concealed beneath younger Codroy Group strata in St. Georges Bay. A buried, west trending fault north of the Anguille Mountains may, however, have originally delineated the northern margin of the subbasin during the accumulation of the Anguille Group (Belt, 1969). Belt rightly favoured this fault because of the great thickness difference between the Anguille Group in the Anguille Mountains and the Fischells conglomerate member in the Flat Bay anticline. It is quite probable, however, that Belt's faults joined with the fault along the northwest margin of the subbasin as a single splay of the Long Range fault. The subbasin, hence, could have evolved in the divergent zone between the two faults (Figure 17A); (5), the basal Ship Cove Formation of the Codroy Group is a regional marker which allows the history of tectonic uplift of surrounding uplands, in particular the Humber Arm allochthon highlands, to be equated with the evolution of the Anguille Group within the subbasin.

Conglomerates containing detritus from the Humber Arm allochthon highlands occur at two main stratigraphic intervals and in widely separate geographic locations. The first and older conglomerates are found at the base of the Friars Cove Formation and can be traced along the northwest limb of the Anguille anticline as thin beds in dominantly gray, fluvial sandstones. Nowhere are they as thickly bedded, coarse and full of Cambro-Ordovician carbonate and siliciclastic pebbles as at Cape Anguille in the extreme southwest of the subbasin. Even allowing for resedimentation of the Cape Anguille conglomerates from margin to axial region of the narrow basin, these deposits are clearly proximal and must have once lain close to a rugged upland adjacent to their present geographic position. This must imply that either (1) Cambro-Ordovician rocks extended southwestward from the Port au Port Peninsula to cover most of the area now occupied by St. George's Bay, a distance of 50 km, or (2) that the source rocks have moved by as much as 95 to 120 km by right lateral, strike-slip fault movements after the Cape Anguille conglomerates were laid down.

The second major conglomerate sequence, the Fischells conglomerate member, includes some of the youngest rocks of the Anguille Group and it is geographically restricted to the north of the subbasin. The conglomerates are clearly proximal and are interpreted to have been deposited upon an alluvial fan that must have once been rooted against the northwestern upland. Since the conglomerates lie unconformably upon Precambrian crystalline basement, it appears that either (1) the Lower Paleozoic supracrustals were already eroded from the area by late Anguille times or (2) the conglomerates were deposited upon a floundering block of previously uplifted basement along the southeastern margin of the highlands which shifted northeastwards some 60 km after the conglomerates were deposited. The latter interpretation implies a major episode of wrench movements in late Anguille - early Codroy times.

Two tectono-sedimentary models are thus possible for subbasin evolution during the deposition of the Anguille Group. The first model involves the development of a simple graben-horst, rift system which was activated after thick Devonian molasse was laid down in a broad successor basin. In this model, the graben formed due to extension, block faulting and crustal thinning. Mountains were uplifted southeast of the Long Range fault and northwest of the subbasin. Tilting of the Clam Bank Formation at the west end of the Port au Port Peninsula possibly occurred during this event.

Uplift was followed by denudation of both the poorly consolidated Devonian molasse and the underlying Lower Paleozoic rocks of the Humber Arm allochthon highlands to provide detritus for the Snakes Bight Formation. Conglomerates rich in large pebbles of carbonate, quartzite, mafic volcanics and granites derived from erosion of the Lower Palaeozoic strata, and Grenvillian basement in the highlands, reached the subbasin at the beginning of the Friars Cove Formation. With time, the upland was gradually reduced in elevation and areal extent. The southeastern margin of this west trending mountain ridge would have lain close to a fault that is postulated to strike southeast beneath St. George's Bay from the vicinity of the Flat Bay anticline (see SMAP on Figure 15). The mountain front retreated northward in the semiarid climate due to pedimentation so that, by late Anguille times, conglomerates were deposited upon Precambrian crystalline basement at Flat Bay, north of which they thinned rapidly. Consequently, by the commencement of Codroy deposition, the mountains were reduced to a relatively low-lying ridge (hereafter called the Port au Port ridge), onlapped by flat-lying, thin, Codroy Group strata (Figure 15).

The second model assumes that the subbasin and surrounding uplands were fashioned by major, right-lateral, strike-slip movements related to the development of the Cabot Fault system (Figure 16). The Deer Lake Basin also formed within this fault system and has been accredited an early, wrench-fault history by Hyde and Ware (1981).

A brief introductory discussion of wrench-fault systems will aid in assessing the history of the subbasin within such a system. Faults in such systems are commonly long, relatively straight and in many cases bend, splay and braid locally. Numerous minor faults trend and splay parallel or subparallel to the main wrenches but cross faults are also prominent. Compressional and extensional stresses both occur between fault splays, braids and bends of the fault system. Significantly, this means that uplift and subsidence of fault-bounded blocks and wedges may occur concurrently or intermittently and over widely spaced distances along the system (Crowell, 1974a; Reading, 1980). Lateral displacement may reach several hundred or more kilometres. Much of this movement is accommodated by displacements of a lower order of magnitude on the constituent faults in the system (Crowell, 1974a). Synthetic and antithetic faults can have different displacement vectors and folding commonly occurs in association with these structures. The locus of movement may shift from one fault to another with time. Depositional basins form along or between one or more wrench faults where they bend, splay or lie parallel to one another. These include pull-apart basins at bends or splays, depressions at fault bends and where crustal stretching occurs, and wedge-shaped basins between divergent faults (Crowell, 1974b). Basin fills are often very thick and frequently show systematic changes in thickness and age of sedimentary fill revealing how the basins evolved. (Crowell, 1974b, 1979; Reading, 1975, 1980; Steel, et al., 1977; Steel and Aashiem, 1978; Bluck, 1978, 1980).

Figure 16 displays the present-day distribution of faults, geologic terranes and Carboniferous sedimentary basins associated with the Cabot Fault system. It clearly shows many features of a strike-slip system as previously indicated by Belt (1969). Faults are long and straight but they bend locally and there are numerous fault splays. The associated basins are long and narrow and contain thick basin fills, some of which were deformed between episodes of sedimentation, as, for example, the Anguille Group in the Deer Lake Basin (Hyde and Ware, 1980, 1981). Although deformation did not interrupt sedimentation in the Bay St. George subbasin, the thickness and distribution of rock units in the Anguille Group shows a systematic change from southwest to northeast. In the southwest, the succession consists of 3200+ m of Kennels Brook Formation overlain by 1600 m of Snakes Bight and Friars Cove Formations immediately below basal Codroy limestones. In the north of the Anguille Mountains, the succession is dominated by the younger Friars Cove and Spout Falls Formations. These formations have an accumulative thickness of at least 3500 m, overlying perhaps 1000 m of Snakes Bight Formation and an unknown thickness, if any, of Kennels Brook Formation. This suggests that two basin-fills occurred. The older basin-fill was restricted to the southwest of the subbasin and was dominated by the Kennels Brook Formation. The younger basin-fill, composed mostly of strata of the Friars Cove and Spout Falls Formation, lay northeast of the first which it also partly overlapped.

Circumstantial evidence that supports the wrench tectonic origin for the Bay St. George subbasin includes:

(1) the northeastward displacement of the Humber Arm allochthon highlands by at least 120 km prior to the deposition of early Codroy Group strata;

(2) the deposition of thick Carboniferous sedimentary sequences in narrow basins, implying not only substantial subsidence but adjacent uplift of source areas. These uplands persisted and continued to supply detritus to the subbasin throughout Friars Cove and Spout Falls time;

(3) the deposition and deformation of the Anguille Group in the Deer Lake Basin prior to the deposition of the Visean Deer Lake Group (Hyde, in press; Hyde and Ware, 1981);

(4) the distribution of lithofacies and formations in the southern Anguille Mountains as compared to those in the north of the mountains. This indicates that the locus of deposition shifted northeastwards with time. The subbasin probably extended in a southwestward direction and it is most readily explained as a pull-apart basin (cf. Bradley,1982). Considerable thickening of the Anguille Group southeastward across the Snakes Bight fault demonstrates that it was probably an active growth fault at least during deposition of the Friars Cove and Spout Falls Formations;

(5) right lateral, post-350 Ma wrench movements have also been

proposed along the Green Bay fault (Hibbard, personal communication, 1981). This fault offset the Baie Verte line, probably in the Early Carboniferous, since flat-lying, possibly Pennsylvanian conglomerates are inferred to lie in depositional contact with the same structure (Hibbard, personal communication, 1981). Wrench movements in the central Newfoundland uplands have also been postulated to offset the limbs of a major Acadian syncline across the Green Bay fault by some 20 km of right-lateral displacement (Upadhyay, 1973).

The margins of the subbasin during deposition of the Anguille Group are not easily defined. The main structural feature of the area is of course the Long Range fault which was probably the southeast margin of the subbasin at this time. This fault is believed to have accommodated most of the wrench movements that created the subbasin, although it is clear from sediment provenance studies in the Anguille Group that substantial uplift also occurred southeast of the fault.

The northern and northwestern margins of the subbasin were formed by a right-lateral curved splay of the Long Range fault as discussed above. The splay (Figure 17A on Foldout B), which was later covered by strata of the Codroy Group, likely had a complex history. The fault provided the locus upon which basin pull-apart occurred and displaced terranes moved. The occurrence of an older and a younger basin-fill sequence in the Anguille Group suggests that the fault was the northern basin margin in the Late Devonian and again in the Early

Mississippian. If both basin-fills were associated with the splay fault, then clearly the older sequence was subsequently displaced some 20 km to the southeast of the original boundary. A west trending magnetic lineament (Geological Survey of Canada, 1971) that is located about 20 km south of the postulated splay fault may well represent the subsurface expression of the northern margin of the first pull-apart basin (Figure 17A). Toward the end of the depositional history of the Anguille Group, however, the curved splay fault is believed to have straightened so that it extended northeastward to cut the Steel Mountain anorthosite. Consequently, basin pull-apart was to cease gradually during the early stages of deposition of the Codroy Group because of the straightening (Lensen, 1958). This is perhaps reflected in the change of subbasin width and shape that occurred during the first phases of Codroy sedimentation.

The southwest margin lies somewhere beneath the Gulf of St. Lawrence. It may coincide with a nearly north trending ridge of pre-Carboniferous rocks that Howie and Barss (1975a) show 15 km offshore of Cape Anguille (Figure 17A and B); they show the ridge as covered by thinned Carboniferous cover.

In the wrench-fault model, two major pulses of basin extension probably occurred during deposition of the Anguille succession (Figure 17A and B). The first pulse created the pull-apart basin into which the thick Kennels Brook Formation accumulated. This early-stage basin was probably limited by (1) the southwestern basement ridge of Howie and Barss (1975a) and (2) a west trending fault now delineated by the west trending magnetic lineament (Figure 17A). The distribution of the upper 1000 m of the Kennels Brook Formation north of this lineament suggests that basin subsidence and extension continued gradually so that the first-pulse margin in the north of the basin was overstepped by the Devonian sediments.

A second pulse of accelerated subsidence and extension then occurred in the pull-apart basin to create a new depository northeast of the first. Deposition of the 3500+ m succession of fluvial Friars Cove and Spout Falls sediments followed. The northern basin margin probably coincided with the west trending fault postulated by Belt (1969, see his Figure 1) to the north of the Anguille Mountains. Eventually upper Anguille strata overstepped this margin northeastward (Figure 17B) along the subbasin axis so that a thin succession of upper Anguille sediments covered basement before the deposition of the thick, basin-fill sequence belonging to the Codroy Group (Figure 17B).

A synopsis of the basin development may thus be summarized within the wrench model (Table 3) as follows:

1. Commencement of dextral wrench movements in the Devonian on the Long Range fault and other faults of the Cabot Fault system.

2. A pull-apart or wedge basin developed at a bend or splay of the Long Range fault southeast of the Steel Mountain anorthosite. The first pulse of basin pull-apart was

followed by gradual basin extension so that deposits of the Kennels Brook Formation overstep the northern boundary of the subbasin.

3. Uplift of the Humber Arm allochthon highlands led to the formation of a narrow, deep-water, lacustrine basin in which the Snakes Bight Formation was deposited.

4. Basin extension accelerated during a second pulse of basin pull-apart. The Humber Arm allochthon highlands moved northeastward over a distance of some 60 km during the second phase of basin extension.

5. Fault blocks foundered locally in the northeast of the basin toward the end of Anguille sedimentation. Northeastward displacement of the Humber Arm allochthon highlands continued for perhaps a further 60 km before or during the early Visean. Deformation of the Anguille Group is minimal because the subbasin lay between divergent faults and pull-apart caused extension rather than compression (Crowell, 1974a and b).

This model of basin extension resembles that proposed for Upper Old Red Sandstone strata of the Midland Valley of Scotland by Bluck (1980) and the Devonian Hornelen Basin of Norway (Steel et al., 1977; Steel and Aashiem, 1978). It is also favoured for the Bay St. George subbasin by Belt (personal communication, 1981) who first suggested the idea to the author.

Interpretation of the evolution of the subbasin within a major dextral wrench fault system contradicts recent models based upon paleomagnetic data that suggest the Devonian-Carboniferous faults of Maritime Canada including the Cabot Fault system were part of a large scale sinistral wrench system (Kent and Opdyke, 1978 and 1979; Irving, 1979). The data presented here in a local study however, supports the broad regional conclusions of a right-lateral, wrench-fault history for the Maritimes Basin during the Devonian and Carboniferous as suggested by Bradley (1982).

Part 3 - Codroy Group

Introduction and Definition

The Codroy Group is a mixed sequence of marine and nonmarine strata, 4000-6000 m thick, that includes siliciclastic, evaporitic and calcareous sedimentary rocks. Previous studies (Hayes and Johnson, 1938; Bell, 1948; Riley, 1962; Baird and Cote, 1964; Belt, 1969; Table 1) did not attempt to define a lithostratigraphy for the group, except in a very general way, and little attempt was made to correlate rock sequences from various parts of the subbasin.

The Codroy Group is defined here to include all rocks between a basal limestone, the Ship Cove Formation, and the first continuous deposits of fining-upward, coarse grained, gray, arkosic sandstones and red siltstones, the Barachois Group. Similar fining-upward sequences also occur in the upper part of the Codroy Group but there they are locally intercalated with marine beds and limestones. The upper contact is difficult to define accurately because of poor exposure and faulting, but it is probably both gradational and diachronous. Basal strata of the Codroy Group lie with apparent conformity upon the underlying Anguille Group at most localities in the Bay St. George subbasin. In places, the Ship Cove limestone does not form the local base of the Codroy succession. Instead, younger, undivided strata rest unconformably on Precambrian or Lower Paleozoic basement (e.g., along the east margin of the Indian Head Complex) and in isolated pockets in a number of places along the south side of the Port au Port Peninsula.

Four formations, the Ship Cove, Codroy Road, Robinsons River and Woody Cape Formations, make up the internal stratigraphic subdivisions of the group (Table 4) (Knight, 1983). The divisions are based upon lithological criteria and are supported by paleontological control where possible. The Robinsons River Formation is subdivided into four members: the Jeffreys Village, Highlands, Mollichignick and Overfall Brook Members. Correlation of rock units is shown in Table 4. Biostratigraphical control within the Codroy Group has previously followed Bell's (1929) A to E subzones of the Windsor Group in Nova Scotia (Hayes and Johnson, 1938; Bell, 1948; Table 4 and 10). The zones have been extensively applied in the Maritimes Basin (Stacy, 1953; Sage, 1954; Kelley, 1967b; Moore, 1967, Moore and Ryan, 1976.) They are being refined by further macrofaunal, microfaunal and microfloral studies. In the Bay St. George subbasin, this work includes macrofaunal studies by McGlynn (personal communication, 1978), microfaunal studies by Mamet (1968), von Bitter (1975), and von Bitter and Plint-Geberl (1978, 1979, 1982) and investigations of miospores by Utting (personal communication).

Only the basal Ship Cove Formation and the succeeding Codroy Road Formation maintain continuity throughout the subbasin. Major faults interrupt the succession near the top of the Codroy Road Formation. Poor exposure also means that and the exact inter-relationships of the remaining formations and members is incompletely understood.

Distribution

The Codroy Group underlies two extensive areas of the subbasin (Figure 4). The main exposures occur in the St. Georges Bay lowlands north of the Anguille Mountains where rock units include the Ship Cove and Codroy Road Formations, the Jeffrey's Village and Highlands Members of the Robinsons River Formation, and the Brow Pond lentil.

The Codroy Group, however, also occupies much of the Codroy lowlands southeast of the Anguille Mountains. There it includes the Ship Cove and Codroy Road Formations, the Jeffrey's Village, Mollichignick and Overfall Brook Members of the Robinsons River Formation and the Woody Cape Formation. Basal Codroy strata occur in fault zones and in synclinal folds within the Anguille Mountains.

Description of Formations

Ship Cove Formation

Definition and distribution

The Ship Cove Formation is the name given to a widespread and uniform deposit of limestone that forms the basal unit of the Codroy Group. The unit was originally called the Ship Cove limestone and was named after Ship Cove (Bell, 1948) on the northwest flanks of the Anguille Mountains. The type section occurs at the falls near the mouth of Ship Cove Brook. It is also well exposed on Codroy Island, in many streams that cross the flanks of the Anguille Mountains and Bald Mountain, and in tight synclinal folds within the Anguille Mountains. The formation is folded around the Flat Bay anticline, outcropping along Fischells Brook and Northern Feeder. It is also recorded in drill holes penetrating gypsum deposits at Flat Bay (McKillop, 1959), Heatherton (Rose, 1947), and near Highlands River (McKillop, 1953a). Baird (1949) records limestone float along Coal and Sheep Brooks near the Steel Mountain anorthosite. Along the northern margin of the subbasin, it is exposed on Romaines Brook and was intersected by drill holes at the base of the Romaines gypsum deposit (McKillop, 1959). A similar limestone near Boswarlos and shelly limestones at Aguathuna on Port au Port Bay are also correlated with the Ship Cove Formation (von Bitter and Plint-Geberl, 1982).

The Ship Cove Formation sharply and conformally overlies sandstones of the Friars Cove Formation and Spout Falls Formation in the Anguille Mountains and Bald Mountain. At Fischells Brook, it lies conformably upon sandstones and conglomerates of the Fischells conglomerate member. This abrupt change from coarse siliciclastic rocks to laminated limestone across the contact supports the assumption of a disconformity in the north of the subbasin. The basal contact on Codroy Island is, however, gradational; Ship Cove limestones are interbedded with sandstones of the Friars Cove Formation.

The upper contact of the Ship Cove Formation is mostly covered, but in section K295 and K214 (Figure 18) and in drill logs (Smith, 1953; McKillop, 1959), it appears to be conformable and sharp with the overlying Codroy Road Formation. The formation is overlain by red siltstones in the south of the subbasin but by gray shales and gypsum north of the Anguille Mountains. At Fischells Brook and in drill logs at Heatherton (Rose, 1947) it appears to grade up into gypsum and thin gray shales, but has been replaced by growth of displacive gypsum at Flat Bay and Romaines Brook (McKillop, 1959).

Thickness

The formation is fairly uniform in thickness, averaging 18 to 20 m. It may, however, be somewhat thinner in the southwest of the Anguille Mountains where only 13 m was measured in section K295 (Figure 18). On Fischells Brook, approximately 22-25 m is exposed, yet just 8 km to the north in the Flat Bay gypsum mine, drill holes penetrated only 5.7 m beneath gypsum (McKillop, 1959); approximately 8 m was recorded in drill holes near Heatherton (Rose, 1947). Thicknesses at Romaines Brook from outcrop and drill hole information (McKillop, 1959) vary between 2 and 11 m; 2 to 4 m occurs in equivalent strata on the north side of the Port au Port Peninsula.

General lithology

The Ship Cove Formation is composed of well laminated, gray limestones that become shalier upward where they contain numerous gypsum molds. The succession is generally consistent throughout the Anguille Mountain but differences occur in the north and south of the subbasin (Figure 18).

In the Fischells Brook area, shales and thin sandstones are interbedded with the limestones at the base of the formation (Figure 18). Belt (1969) separated this basal shale from the Ship Cove Formation. Fossils are also more common in the north of the subbasin and include small, whole, smooth-shelled brachiopods (possible *Composita*, cf. Moore and Ryan, 1976). Conodonts occur throughout the 3 m section at Romaines Brook, although they are restricted to the basal also occur higher in the formation within laminated limestones. The packstones generally form less than 5% but locally 15% of the formation. The facies is made up of undulose, 1-5 cm thick layers of buff to pale gray weathering, blue-black, structureless packstones and wackestones which are separated by millimetre thick laminations of lime mudstone.

Large, straight, widely-spaced, low amplitude ripple-marks occur at Ship Cove (Plate 31). The ripple crests trend 230° and are composed of size-sorted carbonate granules; troughs consist of fine lime sand. Horizontal, randomly-orientated trails occur on basal bedding surfaces in the facies along Fischells Brook, Highlands River and Northern Feeder. The packstones and wackestones (Dunham, 1962) consist of generally poorly sorted, sand to fine, pebble-siz grains which include mostly pellets and peloids (Plate 32) (Bathurst, 1975). Rounded to angular intraclasts, oncolites, aggregates, some ooids and rare fossil debris are also present. The latter is most common in the north of the subbasin; articulate brachiopods, ostracods, fish scales, broken tubular bryozoa and calcispheres are commonly found. The calcispheres, which have not been observed south of K179 (Figure 18) except at Ryans Brook, consist of structureless spheres of single calcite crystals and of solitary and colonial 'coccoid-like' spheres (Plate 33). The latter have a fine, tangential, wall structure (possibly a calcitized sheath). Serpulid worm tubes, possible gastropods and fragmented ostracods occur in the facies 2 km upstream from the road bridge at Ryans Brook. Packstones at the bridge itself, however, lack any skeletal fragments. Scattered terrigenous silt and carbonaceous material occurs in the limestones in general.

Neomorphism is widespread. Skeletal grains and dark micrite, which originally formed the pellets, peloids and matrix, are replaced by microspar (0.01 mm crystal size) (Plates 33). Recrystallization affects grains selectively in some layers and may obliterate original grain shapes.

Brown to clear, fine, acicular, radiating, isopachous cements coat and line cavities in whole and compacted shell fragments. Radial to blocky clear spar fills the remaining spaces in these skeletal fragments and, in some instances, the spar is in optical continuity with the peripheral, acicular cement. The isopachous layers were fractured prior to the precipitation of the clear spar, supporting an early origin for the drusy layer. Stylolites cut both shells and acicular cements.

Interpretation of lithofacies A: Lithofacies A is comparable to lithosome A of the Macumber Formation in Nova Scotia (Schenk, 1967a and b). It is interpreted as a low-energy, shallow subtidal deposit of pellet- and peloid-dominated, lime mud. The facies is similar to that forming in many shallow shelf and lagoonal environments of modern-day carbonate production, such as the Persian Gulf (Kendall and Skipwith, 1969; Purser and Evans, 1973), Bahamas (Bathurst, 1975) and Shark Bay, Australia (Hagan and Logan, 1974a and b). This interpretation is supported by the presence of pellet aggregates, oncolites, ooids and skeletal components. Calcispheres resemble those of the Macumber

Formation, Nova Scotia (Mamet, 1970) and modern Dasycladacean algae that flourish in warm, sheltered, back-lagoon areas of the Florida Keys (Marszalek, 1975).

Many of the pellets in the packstone resemble fecal pellets of modern environments. The sparse fauna suggests, however, that many of the micrite peloids may have been precipitated by algal activity as in hypersaline pools of the Gulf of Aqaba (Friedman et al., 1973) and Laguna Mormona, Baja California (Horodyski et al., 1977). Alternatively, they might have formed by algal degradation of various grains as in Shark Bay, Australia (Read, 1974; Logan, 1974), the Bahamas (Bathurst, 1975) and the Persian Gulf (Taylor and Illing, 1969; Kendall and Skipwith, 1969).

Collapse of many shells indicates the packstones have generally undergone some compaction, especially where the mud content was highest. A fibrous, druse cement grew on shells, in some instances before compaction. The presence of acicular radiating cements around skeletal and non skeletal grains may indicate that early, shallow-marine cementation occurred (Taylor and Illing, 1969; Shinn, 1969; Schroeder, 1973; Friedman et al., 1974; Logan et al., 1974; Picha, 1978).

(B) Laminite lithofacies

Description of lithofacies B: Lithofacies B consists of gray to blue-black, bituminous, laminated limestone in sequences 2 to 4 m thick. It occurs above basal lithofacies A, and in units 1.5 m thick interlayered with lithofacies C in the middle of the formation. It represents 20% to 50% of the unit as a whole, varying in amount from section to section.

The limestones consist of millimetre-scale, smooth, planar to undulose laminae which generally have good lateral continuity (Plate 34). Micro-discordances are common, however, and erosional surfaces, a few centimetres in relief and imitated by overlying laminae, were noted. Compositional, color and textural variations produce simple alternating or composite-alternating lamination (Monty, 1976) of which three main types are recognized.

Type 1 consists of light and dark laminae composed of microspar or grainy microspar overlain by dark pyritiferous, carbonaceous, silty lime mudstone (Plate 35) or wackestone (Dunham, 1962). Ghost fabrics suggest that pellets, aggregates and intraclasts originally occurred in the light laminae, which now consists mostly of a mosaic of equidimensional microspar, 0.05 to 0.11 mm in grain size. These laminae are locally brecciated and the fractures are sealed by the overlying dark laminae. Rounded to irregular, gypsum micronodules, as large as 2 mm in diameter, grew displacively in the laminite at K340 and probably at K295 (Figure 18). At the latter locality, mosaic spar has filled moldic porosity of similar shape and size to the nodules of K340.

Type 2, referred to here as silty laminite, occurs in couplets 1 to 10 mm thick. It consists of brown microspar laminae which show evidence of having replaced original micrite, coupled sharply or gradationally with laminae of terrigenous silt or very fine sand (Plates 36 and 37). The latter consist of well-sorted, angular to subrounded quartz, orthoclase, perthite, plagioclase, green biotite, muscovite, and chlorite. The silt laminae vary from one to several grains thick with little carbonate matrix. Grain orientation, apart from some flat-lying micas or graded layers, is generally absent. Black organic films, ferruginous staining and disseminated pyrite occur towards the top of the silt laminae. Some laminae are composed of 50% microspar enclosing scattered, matrix-supported silt grains. These laminae however, have a swirled, clotted texture that suggests breakdown of the original couplets.

Type 3, called fenestral laminite, consists mostly of silt-free microspar overlain by packstone. In some places the packstone is overlain by porous or nonporous microspar. Type 3 is completed by a carbonaceous micrite cap (Plate 38). The packstones are well to poorly sorted and consist of pellets, peloids, coated grains, oncolites, intraclasts, ooids and skeletal grains. Ooid-rich laminae, now mostly recrystallized, occur near Brooms Brook (K56, Table 5; Plate 39) and at Fischells Brook. Locally spherulites (Friedman et al., 1973), consisting of a micrite or microspar core surrounded by radial, brown-colored spar, also occur. Intraclasts are composed of peloid or ooid packstone. Protrusion of grains from the intraclasts may indicate an origin similar to the cemented lumps described from the Qatar Peninsula, Persian Gulf, by Shinn (1969) and Taylor and Illing (1969). Skeletal detritus is similar to that found in lithofacies A. It includes compacted shells in the poorly sorted laminae and uncompacted, complete shells in the well sorted packstone laminae. Brown, fine, acicular cement or clear clusters of radial acicular needles, speckled by black organic(?) residues, lined shell cavities before compaction. Radial mosaic spar in optical continuity with the fibrous druse fills the remaining intraparticle space much as it did in rocks from lithofacies A.

Organic content, disseminated pyrite and micrite (mostly replaced by 0.02 mm microspar) increases upward to form the top of the type 3 couplets. Laminoid and irregular fenestra (Logan, 1974), which are particularly common from Ship Cove southwestward, occur beneath and arch up the carbonaceous, micrite cap. Laminoid pores are up to 3 mm wide and 8 mm long. Clusters of subvertically oriented, skeletal gypsum crystals 1 mm long also underlie the cap in the fenestral laminite on Fischells Brook.

Downward-tapering, silt-filled, microscopic, hairline (Plate 37) to 1/2 cm wide, 2 cm deep fractures cut type 1 and particularly type 2 laminites. Larger fractures also contain brecciated carbonate fragments and were later cemented by spar. The fractures were folded by compaction.

Circular stromatolites, as large as 30 cm in diameter, occur on Codroy Island. They consist of low hemispheroids (Plate 40) displaying a faint concentric pattern of grooves and ridges on the top of the mounds. Mudcracks filled by argillaceous carbonate mud cut the top of the hemispheroids.

Small and large scale deformation, mostly in type 2 laminite, occurs in some sections (Figures 18 and 19) but is especially common on Codroy Island. Smaller sedimentary structures include overturned folds, thrust faults and upturned broken laminae. Associated microfabrics in the silty laminites suggest that the microspar laminae, including those enclosing silt laminae one grain thick, were broken up into rigid, platy fragments. Silt from the thicker silt laminae was dispersed to fill interstices produced during the deformation.

Large scale structures (Plates 41) on Codroy Island include box folds, tight chaotic folds, tepee structures and small thrust and reverse faults. The box and chaotic folds are overlain and locally truncated by undeformed bedding.

Interpretation of lithofacies B: The facies B laminites of the Ship Cove Formation are interpreted as deposits of intertidal to subtidal algal mats which extended over much of the subbasin following deposition of the basal facies A packstones. The abundance of carbonaceous material and the variety of macro- and micro-structures and associated lithofacies (see Table 5) seem to indicate that the laminites accumulated as algal mats in intertidal flats in the southwest; north of Ship Cove they pass into subtidal mats.

Growth and accretion of the algal mats that formed the laminites was encouraged as sediment from two sources moved into the area and was bound within the mat. Pellets, peloids, lime mud and, less importantly, skeletal and other nonskeletal grains were supplied to the flats from offshore lagoons and shoals by tides and storms that flooded the flats.

The second major source of detritus was windblown silt and sand that formed the silty laminites. The composition of the silt and sand, in particular the types of phyllosilicates, points to a provenance southeast of the subbasin. The silty laminites are particularly important in the southwest, where their character supports high intertidal conditions.

In the southwest, intertidal mats are evidenced by: (1) tepee structures (Read, 1974; Park, 1976; Asserretto and Kendall, 1977; Kendall and Skipwith, 1968, 1969) (2) silt-filled fractures; (3) mudcracked, low hemispheroidal stromatolites resembling forms described in shallow pools of the saline flats of Laguna Mormona, Baja California (Horodyski et al., 1977) and (4) fenestral-rich laminite (Shinn, 1968; Logan, 1974; Logan et al., 1974). Tepee structures and related microfabrics (Asserretto and Kendall, 1977) suggest that penecontemporaneous lithification of the algal flats occurred.

Widespread areal development of flat algal mats occurs today where growth is encouraged by low-gradient topography, protected conditions, frequent wetting and by hypersalinity (Kendall and Skipwith, 1968, 1969; Kinsman, 1969; Shinn et al., 1969; Bush, 1973; Logan et al., 1974; Kinsman and Park, 1976; Park, 1976). Algal mat preservation is enhanced by: (1) early lithification (Kendall and Skipwith, 1969; Park, 1977), (2) high salinities that inhibit proliferation of browsing organisms (Garrett, 1970; Logan et al., 1974; Gebelein, 1976) and (3) groundwater conditions on the landward side of the tidal flats that are unsuitable for growth of displacive evaporite crystals (Logan, 1974; Logan et al., 1974; Park, 1977). These conditions were apparently met during the deposition of the laminites of the Ship Cove Formation.

The laminites in the north of the Anguille Mountains are typified by their high carbonaceous and pyrite content, dark coloration and abundance of fenestra. The latter possibly formed as gas bubbles trapped beneath decaying mat. The significant carbonate grains in the laminites, together with the gypsum nodules, suggest that the mats formed in the lower intertidal zone. The laminites between Highlands River and Fischells Brook formed in shallow subtidal conditions. This is supported not only by the associated lithofacies but also by nonskeletal grains, the importance of skeletal grains, the associated lithofacies, and the acicular, drusy cements that fill intraparticle porosity in fossils. The cements strongly resemble shallow, subtidal cements forming along the Trucial coast (Taylor and Illing, 1969; Shinn, 1969).

Ooid-rich laminae and some fenestral laminites probably indicate that local oolite shoals provided detritus to the algal flats near Brooms Brook and near the Highlands River and Fischells Brook.

(C) Moldic argillaceous and shaly laminite lithofacies

Description of lithofacies C: Very fine, argillaceous micrites and shaly micrites, in units one to several metres thick, occupy the upper half of the Ship Cove Formation and comprise approximately 30-50% of the unit as a whole. Facies C is observed to be interlayered with facies B.

The argillaceous micrites are very finely laminated and consist of alternating silt and microspar laminae. They are similar to the silty laminite of facies B but lack organic material. The micrites are rich in moldic porosity that resulted from dissolution of rhomboid crystals that ranged from a few millimetres to 1.5 cm, and rarely several centimetres, in size. Some molds show interpenetrating and swallow-tail crystal shapes. The molds lie at all angles to the lamination they displace and occur with random orientation on bedding planes. Large, flat, circular stromatolite structures, up to 2 m in diameter, are common. The structures consist of a concentric pattern of grooves and ridges (Plate 42).

Mudcracks, silt-filled microfractures, small tepee structures, microscours and cross-lamination, fine breccias, carbonate mudflakes and laminae of nonskeletal packstone are also present.

Interpretation of lithofacies C: The close similarity of lithofacies C to the silty laminite of facies B suggests that it is probably of intertidal to supratidal origin, built up by alternating deposition of carbonate and windblown silt. The ridge and groove pattern of the flat circular stromatolites (Plate 42) resembles that of modern tufted mat (Logan et al., 1974). The latter is known to grow in the middle to upper intertidal zone where drainage is poor or a high water table keeps mat and sediment permanently moist. Evidence of algal mat does not occur in all the finely laminated micrites but microscouring and cross lamination imply erosion and reworking of the fine sediment, perhaps by wind action. Mudcracks and microfractures, small tepee structures and mudflake breccias possibly formed by the reworking of dessicated laminite and support a subaerial origin for the facies.

Gypsum crystals that grew displacively in the laminites compare to porphyroblastic gypsum of the upper intertidal and supratidal zone of the Nilemah Flat, Western Australia (Logan, 1974) and gypsum crystals of the supratidal sabkha flats of the Persian Gulf (Shearman, 1966).

(D) Intraformational limestone breccia lithofacies

Description of lithofacies D: Lithofacies D is found only on Codroy Island and consists of intraformational, limestone-dominated breccias composed mostly of clasts of facies B laminites, some sandstone, and rare, extrabasinal granite pebbles. The 4-20 cm thick breccias (Plate 43) overlie erosive scours, which transgress underlying laminated sandy limestone or sandstone beds. They are also found above nonerosive bases where they may surround upward-protruding tepee structures. The breccias are overlain by undeformed, laminated limestones which blanket irregularities on the top of the beds.

The clasts are mostly angular plates, 1 to 10 cm in length, of silty laminite or microspar laminae. They are rarely deformed, and lie parallel to and randomly within bedding.

Sandstone clasts are rounded and larger in size. Sand grains are scattered between the clasts, although interparticle and shelter porosity (Choquette and Pray, 1970) is common, except where closed by sparry calcite cement.

Pockets of intraformational breccias also occur in deformed laminated limestones but show no evidence of erosion or transportation.

Interpretation of lithofacies D: Lithofacies D breccias are interpreted to be high energy storm deposits laid down in channels or on hard lithified surfaces of the carbonate flat. A storm origin is evidenced by (1) erosive and nonerosive bases, (2) intraclasts derived from adjacent lithofacies, (3) large quantities of debris, (4) high porosity and (5) rare exotic pebbles. The presence of a lithified carbonate substrate at the time of deposition is suggested by nonerosional contacts and by the preservation of tepee structures. The general lack of sorting or clast orientation indicates rapid deposition. The breccias resemble lithoclastic breccias of tidal creeks in the tidal flats of Sharks Bay, Australia (Read, 1974; Hagan and Logan, 1974b). They compare with breccias described and interpreted as channel deposits by Schenk (1967a and b) in lithosome B of the

Macumber Formation of eastern Nova Scotia.

Lithoclasts were possibly derived by erosion of locally brecciated laminite which had previously been deformed and fragmented. This occurred by crystallization pressures as subaerial, vadose cementation and diagenesis affected the tidal flat (Asserretto and Kendall, 1977). Early lithification also probably influenced the nature of the breccias by reducing the amount of fine detritus produced during erosion and facilitating splitting of limestone readily along the lamination to form platy clasts. The granite pebbles probably indicate that the breccias formed close to a pebbly fluvial facies lying landward of the flat.

(E) Oolitic limestone lithofacies

Description of lithofacies E: Lithofacies E consists of oolitic-peloid grainstone and oncolitic-oolitic packstones and is uncommon. It is interbedded with oncolitic packstone of facies A in the Fischells Brook section and also occurs at the base of the type section of the Ship Cove Formation.

Oncolitic-oolitic packstones and oolitic grainstones near Fischells Brook are thinly stratified with 4-6 mm wide trails on the bases of beds. The ooids are mostly recrystallized to microspar and display no internal structure. Skeletal fragments and calcispheres are present. Dark carbonaceous laminae, rich in grains and microspar laminae, interrupt the oolitic grainstones.

The basal oolitic peloid grainstone at Ship Cove is structureless. It consists of micritic peloids and ooids. The peloids are surrounded by a thin layer of brown radial calcite and the ooids display a well developed, radial fabric. Partially micritized, skeletal grains, are surrounded by a similar fibrous calcite.

Interpretation of lithofacies E: Although little information is available concerning bed thickness and shape, or internal structure and relationship to adjacent lithofacies, the ooid grainstones seem to be best interpreted as subtidal ooid shoals deposited under conditions of moderate energy and stabilized by growth of algal mat during quiet periods. Calcispheres, skeletal grains and bioturbation suggest that the deposits formed in seawaters which were not highly saline.

The basal peloid grainstone at Ship Cove is, however, quite distinctive, consisting of fibrous, calcite-coated peloids and spherulitic ooids. These allochems bear a striking resemblance to the grains of a marginal hypersaline pool in the modern Gulf of Aqaba (Friedman et al., 1973). Halley (1977) has suggested that radial ooids and spherulites are indicative of hypersaline conditions. Similar, radially-coated pellets are also described from lithified, shallow subtidal carbonates of Dohat Faishakh, Qatar Peninsula by Taylor and Illing (1969).

(F) Sandstone lithofacies

Description of lithofacies F: Two different suites of sandstones are interbedded with limestones of the Ship Cove Formation. The first occurs on Codroy Island in the south (Plates 44) and the second suite in the north in the Fischells Brook sections and on Northern Feeder of Robinsons River.

The sandstones on Codroy Island (Figure 19) are brown weathering, fine to coarse grained, well sorted, calcareous arkoses and subarkoses that are similar to those of the underlying Friars Cove Formation. They occur in 10-30 cm thick interbeds or lenses within facies B and D. They overlie sharp, nonerosive or erosive, locally channelled bases. The channelled bases crosscut and undercut laminite beds and tepee structures. Pillars of limestone, which are probably the erosional remnants of once extensive limestone beds, protrude upward in some channels. Limestone and calcareous mudstone intraclasts may occur above the scour surfaces. Nonerosive contacts preserve mudcracks and drape over highs in underlying limestone beds.

The sandstones are usually planar stratified or laminated but locally display ripple cross-lamination which gives a westward paleoflow direction. In one channel sandstone, intraclastic sandstone grades up into massive sandstones capped by lamination. Mudcracked shale partings and interlayered sandstone and laminated limestone are also present.

In marked contrast, the sandstones of the Fischells Brook area (Figure 18) consist of green-gray, argillaceous and micaceous, poorly sorted siltstones to fine sandstones interbedded with gray shales and thin limestone beds. The sandstones vary in thickness from 5 to 45 cm and are internally laminated and cross-laminated. Bases carry flute casts, brush marks and load casts, whilst tops are ripple-marked, coated in plant debris and mica, or show parting lineations. They are composed predominantly of angular, in cases splintery, quartz set in coarse calcite cement with patchy clay matrix. Chlorite, muscovite and minor biotite are the dominant phyllosilicates; plagioclase, scattered zircon, green tourmaline, rare garnet, magnetite, sphene and leuxocene complete the detrital suite. Amorphous red to brown oxides coat some of the grains.

Interpretation of lithofacies F: Lithofacies F sandstones from the southwest and north of the subbasin contrast markedly with each other. On Codroy Island, planar-stratified, well sorted sandstones are interbedded with facies B laminites. They were deposited either in channels eroded in the carbonate flats or when floodwater overflowed such channels and deposited sand as a sheet upon the carbonate flat. Westward paleoflow, and arkosic composition suggest an easterly derivation for the sandstones.

The poorly-sorted, argillaceous and micaceous sandstones of the Flat Bay area were deposited subaqueously with shales. Fluted bases, internal structure and soft sediment deformation suggest that the sands were deposited by low-density underflows discharged from a river mouth (Hsu and Kelts, 1978) into the shallow marine environment.

(G) Other rock types

Description of lithofacies G: In some sections in the Anguille

Mountains, some thin beds or partings of green and gray shale or red mudstone interrupt facies B and C laminites. The gray shales are smooth and structureless. Red mudstone is associated with a gray, fine sandstone in the middle of the section at the head of Brooms Brook (K225, Figure 18). The thickest deposits of gray shale occur in the Fischells Brook area where they are interbedded with thin sandstones and limestone beds. Bioturbation, oncolites, oolites, skeletal remains as well as some lime beds with mudchip pavements and small mudcracked surfaces are associated with the Fischells Brook shale sequence.

Interpretation of lithofacies G: Gray shales probably accumulated on the intertidal algal flats where they may have been trapped on the wet mat or have accumulated in shallow pools locally developed on the flats in the southwest. Much of this fine detritus were probably deposited, subaqueously as windblown fines. Red mudstone and gray sandstone in the same area (K225) suggest terrigenous deposits prograded locally over the carbonate flat.

The gray shales that are interlayered with sandstones and thin limestones in the Fischells Brook area accumulated in quiet water from the turbid, muddy discharge of a river. Structures in associated beds suggest the water was generally only a few metres deep and, in some instances, deposits were subaerially exposed.

Paleontology, age and correlative deposits of the Ship Cove Formation

Smooth-shelled brachiopods (Composita sp?, Moore and Ryan, 1976), ostracod fragments and well preserved conodonts are found in the Ship

Cove Formation. An abundant conodont fauna occurs in the basal centimetres of the formation, but is limited to Cavusgnathus windsorensis and one or more species of Diplognathodus (von Bitter, 1975; von Bitter and Plint-Geberl, 1978, 1979, 1982). The conodonts are assigned to the Diplognathodus zone by von Bitter and Plint-Geberl (1982) and the formation to Windsor subzone A (von Bitter, 1975; von Bitter and Plint-Geberl, 1979, 1982). It is strikingly similar, lithologically, to the basal Macumber Formation of the Windsor Group in Nova Scotia with which it is correlated (see Table 10).

Depositional environment of the Ship Cove Formation

Two models of deposition have been proposed for correlative limestones of the Windsor Group of Nova Scotia. The first model interprets these limestones as the deposits of a prograding, tidal flat similar to the modern day Trucial Coast (Schenk, 1967a and b). The second and later model proposed by Geldsetzer (1977, 1978) and Kirkham (1978) interprets limestones of the Macumber and Ship Cove Formations to have been deposited in quiet relatively deep water (20-50 m) following marine flooding of the early Carboniferous inland molasse basin.

The distribution and characteristics of the lithofacies (see Table 5) in the Ship Cove Formation of the Bay St. George subbasin suggest that the formation was deposited dominantly in a tidal flat complex. During deposition, the subbasin was confined by mountains, southeast of the Long Range fault, and by the Port au Port ridge to the north. Subtidal conditions were maintained in the northern part of the subbasin, whilst tidal carbonate flats occurred in the area of the Anguille Mountains. In the north the proposal of a dominantly shallow subtidal environment is supported by the fauna, the extent of bioturbation, the importance of oncolites, pellets and ooids, and the association of limestones with shales and thin turbidite-like sandstones. In the area of the Anguille Mountains a tidal flat complex is evidenced by tepee structures, mudcracks, and channel-bound limestone breccias and sandstones. Further indications are the paucity of skeletal remains in the laminites and the importance of silty and fenestral laminite with some gypsum nodules and stromatolite structures.

Subtidal pelletal packstone and wackestone (facies A) were deposited over much of the area following marine flooding of the subbasin. In the Flat Bay area, however, more than 15 m of shales and interbedded, fossiliferous, oncolitic packstones and thin 'turbidite-like' sandstones are seen below the more typical Ship Cove limestones. They suggest that flooding began earlier and was maintained longer in the north of the subbasin.

Pelletal packstone was not deposited in the Codroy area and here the basal beds of the Ship Cove Formation consist of silty and fenestral laminites. Channel-bound sandstones and limestone breccias within these laminites resemble channel deposits of the intertidal flats of Shark Bay, Australia (Read, 1974; Hagan and Logan, 1974b). Tepee structures indicative of early, subaerial lithification (Asserretto and Kendall, 1977) and low hemispheroidal stromatolites similar to forms found in shallow pools of modern saline flats (Horodyski et al., 1977) together suggest that the landward edge of the tidal flat lay in the Codroy area. Mudcracked horizons are also common. This lateral facies variation at the base of the formation strongly implies a gradual transgression from northwest to southeast rather than a sudden flooding as suggested for the Maritime Basin by Geldsetzer (1977, 1978). It is similar to facies changes described for the recent transgressive history of the basal carbonates of the Trucial Coast (Evans et al., 1969).

As sea level stabilized, the intertidal flat broadened to prograde northward over the basal packstones. The landward edge of the tidal flat was maintained in the southwest. Here it was periodically blanketed by sheetwash sand deposits that were derived by reworking of sand from an exposed alluvial fan, fluvial system or perhaps aeolian deposits that lay along the foot of the paleo-Long Range highlands. In the lower part of the intertidal zone, flat algal mats flourished over a very extensive, low lying, sheltered area that occurred in the central part of the Anguille Mountains. The mats were built up of carbonate detritus washed from offshore (type 1 and 3 laminites) or by windblown sand and silt derived from the landward side of the tidal flat. Decomposition of the mat produced fenestra and disseminated iron sulphides.

Nodular and skeletal gypsum formed in the facies B laminites of the lower intertidal zone. Porphyroblastic gypsum crystals in moldic laminites developed higher in the intertidal zone as salinity of groundwaters increased. However, no advanced nodular gypsum or anhydrite growth occurred, which implies that the tendency for continued concentration of brines in the landward portion of the mats was somehow offset (Bush, 1973; Read, 1974). This was perhaps affected by a number of factors and could have included the presence of fresh meteoric groundwater and high siliciclastic content. In addition, early lithification and impermeability of algal mat layers might have impeded landward movement of marine waters (Bush, 1973). A high water table that kept the surface mat damp may have helped prevent the formation of dessication cracks. Circular stromatolites of the moldic laminite facies resemble tufted mat that grows in areas of poor drainage and/or a high water table on modern intertidal flats (Logan et al., 1974).

The composition of the silt and sand indicates that its provenance was in the area of the Long Range Mountains. This suggests that it was carried onto the tidal flats by a prevailing east or southeast wind that deflated alluvial sediments along the inland edge of the flats. The sediment was probably blown as a thin sheet over the flats (Allen, 1970b; Glennie, 1970). It was trapped on the sticky algal mat, particularly at low tide (Park, 1976), or accumulated in shallow pools on the flats. Park (1976) believes most windblown terrigenous sediment accumulates in the intertidal zone of the Trucial coast and does not reach the offshore. Lack of grading or mineral segregation in the silty laminae is consistent with this hypothesis.

Shallow marine conditions were maintained for much of the history of the Ship Cove Formation in the northern part of the subbasin where a sparse fauna was active. Oncolitic oolite shoals were locally developed. Algae played an important role in binding sediment and micritizing and pelletizing the skeletal and nonskeletal carbonate grains. Submarine lithification is supported by (1) reworking of lithified pellet and ooid packstone, (2) alternation of layers of whole and collapsed shells, and (3) intraskeletal, acicular cements. Similar lithification processes are known in approximately 2 m deep tropical seas (Taylor and Illing, 1969; Shinn, 1969; Picha, 1978). Muddy and very fine, sandy, terrigenous detritus was supplied by rivers discharging into the northeast of the marine basin.

The basin probably became more restricted as sedimentation continued. Evidence of nodular gypsum replacing the top of the Ship Cove limestone at Romaines Brook implies the establishment of a southward prograding tidal flat and sabkha attached to the Port au Port ridge in the north. Similar nodular gypsum at Flat Bay probably implies that the prograding sabkha was extensive or that a separate, evaporitic, tidal flat was established about an arch cored by Precambrian basement rocks.

Redbeds and gray beds and gypsum overlie the Ship Cove Formation in the areas south and north of the Anguille Mountains respectively. This facies arrangement suggest nonmarine beds prograded northward across the subbasin so that the depositional history of the Ship Cove Formation ended when the fine alluvium of the Codroy Road Formation blanketed the deposits of the inland sea.

Codroy Road Formation

Definition and distribution

The Codroy Road Formation is the name given by Knight (1983) for a mixed sequence of fine siliciclastic, carbonate and evaporitic sedimentary rocks that was previously called the Codroy Shales (Hayes and Johnson, 1938) and included in the lower Codroy Group by Baird and Cote (1964).It is not easily defined because the character of the formation is variable from north to south and the generally incompetent strata have suffered strong deformation in the area peripheral to the Anguille Mountains.

The formation is named after the navigation channel that leaves the small harbour of Codroy. In the Codroy area, the formation is exposed in cliffs from Codroy Village south to a major fault just south of Black Point. This fault separates the Codroy Road Formation from the younger Woody Cape Formation. The former formation is also extensively developed along the northeast side of the Codroy lowlands and in the "round valley". A well exposed, coastal section occurs north of the Anguille Mountains near Ship Cove, from where the rocks can be mapped inland to the Highlands River. Both the Codroy and Ship Cove sections are complicated by folding and faulting. The formation is also mapped around the Flat Bay anticline and occurs near Romaines Brook, west of Stephenville. In the north the best exposed, although incomplete, section lies along Fischells Brook east of the Canadian National railway bridge. Quarry workings at the Flintkote gypsum mine at Flat Bay also provide good exposure.

The base of the formation is conformable or gradational upon the shaly carbonates of the underlying Ship Cove Formation. In places it is sited where displacive gypsum has replaced the top of the Ship Cove limestones (see discussion of upper contact of the Ship Cove Formation for descriptions).

The upper contact is not easily defined except at the Fischells Brook section where it is placed at the top of the uppermost gypsum deposit (Figure 20 on Foldout C; unit 8 of section L, Bell, 1948) that crosses the brook near the railway bridge. The upper contact is placed at the top of the Black Point limestone at Codroy and above the gypsum unit that directly overlies the Cormorant limestone at Ship Cove. These two limestone markers are correlated because they are both overlain by fine redbeds with limestone breccias (Codroy Breccias, Bell, 1948) of the Robinsons River Formation. Lack of carbonate at the top of the section on Fischells Brook makes definite correlation of the top contact from area to area impossible. It is felt, however, that the contact defined here represents a distinct sedimentation break in all areas and, furthermore, it quite possibly reflects a common geologic event.

Thickness

The thickness of the Codroy Road Formation is not easily calculated because most sections are structurally complicated. Approximately 145 m of strata were logged in the section along Fischell Brook (Figure 20), although Bell (1948, units 3 to 6, section L, page 33) calculated it to be 244 m thick. The section at Ship Cove is estimated to have a thickness of approximately 120 m. In the Codroy

Valley, the formation may be 300 m thick but the section is badly transected by faults.

General lithology

The Codroy Road Formation has a variable lithological character but always includes fine grained siliciclastic rocks, evaporites and minor carbonates. The fine siliciclastics are represented by red siltstones and fine sandstones and a variety of drab-colored rock types. The latter comprise multicolored laminated siltstones, gray evaporitic shales, and gray to blue-black mudstones and siltstones. The evaporites consist of varicolored gypsum and blue-gray anhydrite. Carbonates include mostly dark gray to black, bituminous dolomites and fossiliferous, dolomitic, mudstones and muddy dolomites; shelly, biohermal limestones or dolomites are also locally present.

Red and gray siliciclastics with interbedded evaporites and minor carbonates comprise the Codroy Road Formation around the Anguille Mountains. Redbeds gradually give way northward of Ship Cove to gray beds and evaporites; north of Robinsons River evaporites become the dominant rock type.

These lithologies arranged in repetitive sequences occur in the Codroy and Ship Cove sections and were logged in drill core near Ryans Brook, Codroy lowlands (McKillop, 1953b). Similar sequences are absent, however, in sections further north and in drill logs at Highlands River (McKillop, 1953a; Smith, 1953). There, most successions consist of a gray facies interbedded with, or overlain by, gypsum and capped by redbeds. Other sequences are made up of gray beds with minor gypsum capped by 10-20 cm thick redbeds, themselves locally containing gypsum nodules. Where carbonates occur in the Codroy Road sequences they overlie gray and black siliciclastics and pass up into gypsum with or without redbeds. At Ship Cove, two megasequences occur; gray beds are generally dominant low in the megasequences but pass upward into the redbeds.

Six lithofacies are defined in the Codroy Road Formation. They are: (A) red siltstone and sandstone lithofacies, (B) multicolored laminated siltstone lithofacies, (C) gray evaporitic shale lithofacies, (D) gray and blue-black mudstone and siltstone lithofacies, (E) evaporite lithofacies and (F) carbonate lithofacies.

(A) Red siltstone and sandstone lithofacies

Description of lithofacies A: Fine redbeds composed either of structureless siltstone or of thin sandstones interbedded with siltstones form units up to 15 m thick in both the Codroy and Ship Cove sections. Thick, structureless siltstones generally weather with a hackly fracture and contain horizons with cubic crystal molds a few millimetres to 1 cm in size. Cross-laminated siltstones from 4 to 20 cm thick lie gradationally within some units.

Green to red, very fine sandstones are as thick as 40 cm. They overlie sharp bases and consist of planar lamination passing up into ripple-drift crosslamination. Parting lineation is exhibited on planar lamination. Small channel scours filled with crossbeds erode into the top of some sandstones; rootlet impressions and mudcracks penetrate the top of others. The sandstones grade up into structureless, green-mottled, red siltstones that may enclose carbonate concretions.

Interpretation of lithofacies A: The red colored, fine grained nature of these sediments, probably indicates that they were alluvial plain deposits. The current bedded sandstones were likely deposited by shallow intermittent streams with sheetfloods or perhaps wind reworking the fine alluvium. Mudcracks, limited distribution of plant rootlets, presence of caliche nodules (Gile et al., 1966; Leeder, 1975) and horizons of salt molds all indicate that the climate was at least semiarid. The salt crystals probably formed within the alluvium close to or on a playa flat by precipitation from groundwater brine (Smith, D. B., 1971; Kendall, 1979a).

(B) Multicolored laminated siltstone lithofacies.

Description of lithofacies B: Multicolored siltstones consisting of gray, red, purple, black, cream and green laminae form units up to a few metres thick in the Ship Cove and Codroy sections. They are associated with other gray siliciclastic rocks. The siltstones are finely laminated on a millimetre scale and consist of rhythmic alternations of muddy, medium to coarse siltstones grading up into silty mudstones. Some thicker, very fine sandstone laminae may also occur. On a large scale, the laminations appear planar and regular, but polished surfaces reveal small scale crenulation, disruption, rupture and irregular thickness of the laminae. Soft-sediment deformation such as convolution and faulting affect 0.5 to 1 cm layers and millimetre-scale load casting also occurs, giving the lamination a ptygmatic, bulbous appearance. Cubic pyrite crystals and cubic halite molds speckle the lamination.

Silt and sand laminae consist of angular quartz grains together with muscovite, green and brown biotite and chlorite. Authigenic rhombic dolomite is scattered in some laminae.

Interpretation of lithofacies B: The graded, delicate lamination and widespread halite pseudomorphs and molds suggest that lithofacies B was laid down subaqueously in quiet, hypersaline, water bodies. The graded laminae reflect the periodic influx of sediment into the water body with density and size settling producing the grading. Microscopic and small scale deformation formed in response to compaction and loading.

(C) Gray evaporitic shale lithofacies.

Description of lithofacies C: Lithofacies C is particularly important from Ship Cove to Robinsons River but it also contributes to the section at Codroy. Evaporitic shales are also known from drill core in the Highlands River and the Fischells Brook areas where they occur between sulfate evaporites. In the Ship Cove area, 10 to 15 m of gray shale and some red, gypsiferous shale form the basal unit above the Ship Cove limestones. Lenses of selenite and beds of argillaceous, sugary gypsum are intercalated with the shales. Traced northward, the facies becomes sandier.

Interpretation of lithofacies C: The gypsiferous shales were deposited as argillaceous particles that continuously settled to the bottom of a quiet, muddy, hypersaline water body. Lensoid deposits of selenite crystals may indicate that rafts of gypsum formed on the bottom as the water body became supersaturated with $CaSO_4$. They may have formed in a similar fashion to those described from the marginal saline pools of the Gulf of Aqaba (Eckstein, 1970). Beds of argillaceous, sugary gypsum were deposited when supersaturation lasted for prolonged intervals. The waters were probably aerobic as pyrite is absent.

(D) Gray and blue-black mudstone and siltstone lithofacies

Description of lithofacies D: Sediments of lithofacies D occur in units 40 cm to 17 m thick in the Codroy and Ship Cove sections where they are associated with facies B and interlayered with facies A. They are composed mostly or completely of pale gray siltstone and mudstones or less commonly of blue-black to black mudstones interbedded with gray sediment. The gray siltstones form sheets 2 to 15 cm thick within the mudstones and there they are massive, thinly stratified, laminated or cross-laminated. The gray siltstones are generally graded, passing up into structureless or laminated gray mudstones. Molds after cubic halite, 2 - 5 mm in size, are common in both rock types. Interrupting the gray sediments are structureless or laminated, blue-black or black, waxy mudstones. These rocks are rich in fine pyrite cubes and form layers as thick as 1 m.

Interpretation of lithofacies D: The abundant halite molds in lithofacies D suggests that it was deposited in a hypersaline, subaqueous environment like facies B with which it is intercalated. Relatively thick, graded, laminated and current bedded siltstones probably indicate that facies D was deposited close to the margins of a water body by decelerating bottom currents. Fines settled out from suspension when currents waned, so that the siltstones give way upward to mudstones. When stagnant, anaerobic conditions prevailed in the water body, the black, pyritiferous mudstones were laid down.

(E) Evaporite lithofacies

Description of lithofacies E: The gypsum and anhydrite in the Codroy Road Formation occur throughout the subbasin. Gypsum is mostly found in surface exposures but passes underground into anhydrite (Baird, 1951; McKillop, 1959). Previously, four gypsum zones had been delineated in the Codroy Group by Bell (1948) and Baird (1951). The formation as defined here includes the two lower zones A and B, which should not be confused with the biostratigraphic subzones of the Windsor Group.

Zone A evaporites are 60 to 150 m thick. They occur immediately above the Ship Cove Formation in the north of the area at Romaines Brook (McKillop, 1955, 1959), around the northern end of the Flat Bay anticline (Baird, 1949, 1951; McKillop, 1959) and at Sheep Brook and Coal Brook (Baird, 1949, 1951). The evaporites of zone A appear to thin southward from the Flat Bay area, becoming interbedded with gray shales and siltstones near Robinsons River, Ship Cove, and in the Highland Rivers area near Bald Mountain (McKillop, 1953a; Smith, 1953). The evaporite zone appears to be poorly developed in the Codroy lowlands where fine red and gray beds are intercalated with impure, 1 to 5 m thick gypsum beds (McKillop, 1953b).

Zone B evaporites occur higher in the Codroy Road Formation. They are commonly associated with gray shales and siltstones, red siltstones and black carbonates. This second evaporite lithofacies is found with the Black Point and Cormorant limestones and a series of carbonates in the "round valley" area. At least three gypsum beds are present in the Codroy area below the Black Point limestones and three are also associated with dark limestones in the Highlands River area (McKillop, 1953a; Smith, 1953). At Ship Cove, gypsum of zone B overlies the Cormorant limestone. The upper gypsum unit in the Fischells Brook section (interval 8, Section L, Bell 1948, p. 33) may be equivalent to zone B gypsum but there is no obvious break in the succession to separate Zone A from Zone B gypsum (Figure 20).

In the northern part of the subbasin, the evaporites consist of (1) white, gray, black, red and yellow (Baird, 1951), fine and powdery to massive and sugary, crystalline gypsum, (2) coarse to needle-like selenitic and fibrous gypsum and (3) blue-gray, massive, crystalline anhydrite. Fibrous gypsum veins commonly cut associated strata some distance away from the main evaporite bodies. Thin interbeds, laminae and partings of gray shale, limestone, buff crystalline bituminous dolomite and shaly dolomite occur within the evaporites. Clear halite forms streaks locally in the gypsum at Flat Bay.

The deposits at Flat Bay, Fischells Brook and Romaines Brook are well bedded (Plate 45) with local discontinuity surfaces separating sequences with slightly differing bedding attitudes. Massive, contorted, and ropy bedding (Plate 46), and mosaic, distorted mosaic, bedded mosaic and nodular mosaic structure (Plate 47) (Maiklem et al., 1969) are observed in the gypsum. Mosaic structure is most common and forms beds 2 - 6 cm thick separated by 2 mm to 2 cm laminae of carbonate or shale. Enclosed within the nodular structure of the mosaics are remnants of carbonate or shale laminae. These thinly stratified and laminated carbonates make up beds as thick as 40 cm. The laminations are buckled, folded and thrust faulted by synsedimentary deformation (Plate 47). Beds lack lateral continuity because of the destructive growth of the nodular gypsum.

White-colored, gypsum laminites (Plates 48 and 49) occur near the base of the Fischells Brook section and are composed of planar laminae of gypsum and dolomite. Gypsum laminae consist of a felted mat of gypsum needles, whereas dolomite laminae contain scattered silt detritus. They include structures reminiscent of LLH stromatolites (Logan et al., 1964) (Plate 48) and the stromatolitic gypsum of the Solfifera Series of Sicily (Hardie and Eugster, 1971). Displacive nodular gypsum and enterolithic folds are also common (Plate 49) (Shearman and Fuller, 1969).

Grass-like, coarsely crystalline selenite (Schreiber et al., 1976) is noted in one of two gypsum beds that overlie the Cormorant limestone. These beds are separated by gray shales. The selenite occurs in layers a few centimetres thick. It is composed of elongate, rhomboid, gypsum crystals that appear to have been nucleated upon the surface of the underlying shale and grew perpendicular to the basal bedding plane. The lower bed displays distorted mosaic structure (Maiklem et al., 1969) and sits above the limestone.

The gypsum deposits in the vicinity of the Anguille Mountains are generally severely affected by the deformation of the host rocks. The deposits in the Codroy area, for example, appear to be vertical dikes, sheets and plugs. Despite their cross cutting relation with bedding, some are still essentially in their original stratigraphic position. In the mobilized deposits, however, gypsum is characterized by a light and dark banding produced by needle-like selenite crystals 0.5 to 1 cm long, aligned parallel to banding. Flow folds and pinch and swell structures are common; fragments of black, argillaceous, bituminous, locally fossiliferous dolomite, some 1 m in size, are irregularly distributed in the banding. Veins and large areas of coarse crystalline selenite also occur. Locally, the gypsum displays mosaic and bedded structure. Ribbon-like banding of gypsum and gray shales is recorded in a drill log from near Ryan's Brook (McKillop, 1953b). The descriptions also suggest nodular gypsum displacing red siltstone as well as the interlayering of the gypsum and the gray beds.

Interpretation of lithofacies E: The well bedded, predominantly nodular gypsum found in the north of the subbasin displays only minor discontinuity and no evidence of large scale erosion, channelling or slumping. This suggests the evaporites formed within a relatively stable, sabkha environment. Here they grew displacively within gray shales and laminated carbonates which also preserve tepee structures. Such structures may indicate an origin on intertidal or supratidal, carbonate-evaporite flats (Shearman, 1966; Kendall and Skipwith, 1969; Evans et al., 1969; Asserretto and Kendall, 1977). Replacement of the limestones at the top of the underlying Ship Cove Formation at both Romaines Brook and Flat Bay (McKillop, 1959) strengthens this conclusion.

Other types of gypsum are not common but the laminar gypsum of Fischells Brook is noteworthy. Such laminar gypsum may form by rhythmic precipitation of evaporite and carbonate within a standing body of water (Murray, 1964; Kendall, 1979 a & b). This kind of structure may also form by mechanical deposition of gypsum swept from a subaqueous environment onto intertidal algal mat (Hardie and Eugster, 1971) or by coalescing of small displacive nodules within algal mat carbonates (Shearman and Fuller 1969). LLH stromatolitic structure supports the contention that they are intertidal deposits. The presence of small displacive nodules and enterolithic structure also suggests the laminite formed as intertidal mat and was later affected by displacive gypsum growth.

The grass-like selenite of the upper gypsum bed above the Cormorant limestone is similar to selenite-layered structures of Messianian evaporites of Sicily (Hardie and Eugster, 1971; Schreiber at al., 1976). It is also comparable to gypsum crystals in shallow, man-made, brine pools (Schreiber and Kinsman, 1975) and in the shallow waters of Marion Lake, South Australia (Hardie and Eugster, 1971). The selenitic gypsum overlies a lower bed of nodular gypsum of probable sabhka origin, suggesting deposition of the gypsum of the two beds occurred mostly in shallow-water pools or lagoons and in the intertidal zone.

Deformation of the deposits in the south of the subbasin destroyed original features so that environmental comparison with the northern deposits is difficult. Of interest, however, is the presence of the fragmented black dolomites in the gypsum, the association of gypsum beds with the black dolomites or biohermal buildup, and the position of the gypsum between gray siliciclastics below and redbeds above. Where gypsum caps biohermal limestones there is good evidence for the subaqueous precipitation of gypsum. Freshwater vadose diagenesis did not alter the "round valley" reef, for example, before the overlying gypsum was laid down. Where the evaporites form in the gray to red siliciclastic cycles, deposition was probably in shallow restricted or land-locked lagoons. The cyclic sequences seem to imply a number of transgressive-regressive events involving flooding and dessication. In the less deformed units in the southern part of the subbasin, coarse selenitic gypsum is common and these occurrences may also argue for subaqueous deposition (Kendall, 1979b) in lagoons or landlocked depositories.

(F) Carbonate lithofacies

Description of lithofacies F: The carbonates of the Codroy Road Formation are black and buff colored dolomites which are silty and argillaceous. Many lithofacies F carbonates grade into dolomitic, or calcareous, silty mudstones. Limestones do occur but they are subordinate. The best known units are the Black Point limestone of the Codroy area and the Cormorant limestone of Ship Cove (Bell, 1948). Other carbonates are observable at Codroy, along the North Branch River near "round valley", on a southern tributary of the North Branch River near the Long Range fault and on Highlands River near Bald Mountain (McKillop 1953a; Smith, 1953). Some of the lower carbonates on the Barachois River may also belong to this same depositional period.

The uppermost carbonates, the Black Point and Cormorant limestones, although probably deposited at about the same time, clearly have stratigraphic relationships which suggest they are not one bed. They both vary rapidly in thickness from section to section and the Black Point limestone is transgressive when traced from north to south in the faulted coastal section. In the north, the 'limestone' occurs 46 m above a gypsum bed but comes to sit almost directly on the evaporite to the south as intervening redbeds pinch out. At Ship Cove, the Cormorant limestone thins rapidly southward to form a minor limestone bed beneath decimetre-thick gypsum deposits which also cap the thickest part of the bioherm. In the Codroy area brecciated fragments of black carbonate within gypsum indicate that other beds, now destroyed, were once interbedded with evaporites.

Carbonate occurs in the following three modes: (1) black, massive dolomite, (2) argillaceous dolomite or dolomitic mudstones and (3) biohermal limestone.

Beds of finely crystalline, black, bituminous dolomite in the Codroy Road Formation occur in the Codroy coastal and lowland areas, drill hole No. 4 on Highlands River (McKillop, 1953a) and as floating inclusions in gypsum in the Codroy section. Two beds occur at Codroy, the thickest, the Black Point limestone, being 10-21 m thick.

The dolomites are usually massive, thick bedded and brecciated at the base of the beds; breccia clasts are cemented by either dolomite mud or spar. Intercrystalline porosity (Choquette and Pray , 1970) is common. Faint lamination is visible in some beds and the tops are invariably hummocky or nodular. Columnar structures , 4 - 5 cm in diameter and several centimetres high, mark the top of the Black Point limestone (Plate 50). They are coated by a pyritized, millimetre-scale, meshlike pattern of fine rectilinear ridges of possible algal origin. Scattered brachiopods and bivalves (**Schizodus sp.**, Bell, 1948) occur in the "limestones". Cavities, up to 50 cm wide, are lined by black lime mud; red sediment displaying geopetal structure is also present. Solution weathering of unknown age has effected one section of the Black Point limestone. Here it has been weathered to a yellow to brown colored, honeycomb textured rock containing brecciated masses of unaltered, fossiliferous dolomite. The cavities are lined by fine crystalline calcite and siderite and are often partly filled by red and green calcareous mudstone.

Petrographically, the dolomites are composed of brownish dolomite microspar; crystals range in size from 0.005 to 0.01 mm. The microspar is structureless except for some local patches of darker speckling, possibly peloids. Short to branching, 0.1 mm diameter, spar-filled tubules and worm tubes, 0.3 mm in diameter (Plate 51), occur in the dolomites. They possess a concentric-fibrous sheath similar to Serpula (Johnson, 1971). Brown colored, radial-fibrous cement has filled the worm tubes and also replaced the dolomite microspar matrix in patches and spherical and linear zones, perhaps reflecting an organic precursor. Scattered ostracods and siliceous and calcareous microspheres also occur.

Fine to wide fractures that cut the dolomite are filled by coarse dolomite spar and some gypsum.

Oncolitic and fossiliferous, argillaceous dolomites and dolomitic mudstones are common in the vicinity of "round valley" and just north of the Anguille Mountains. In both areas, the fine dolomites overlie gray to black mudstones, and lie between red beds. The finely crystalline dolomites are poorly stratified with indistinct lamination which is disturbed by burrows, 1 to 10 mm across. Fauna include goniatites, gastropods, bivalves, crinoids and coiled foraminifera, possibly Cornuspira (Mamet, 1970) (Plates 52 and 53). The goniatites found were Michelinoceras vindobonense and Dildoceras avonensis. The gastropods and bivalves are both small and thin shelled. They include Lithophagus poolii, Pseudophorus minuta and Stegoceolia abrupta. Shell debris is replaced by white spar which also lines vugs in the carbonate mud.

Shelly bioherms composed of brachiopods and bryozoa, augmented by algae, and rare *Paraconularia*, the straight cephelopod *Michelinoceras*, bivalves and gastropods (Hayes and Johnson, 1938), occur at Cormorant Rock, Ship Cove and on the North Branch River near "round valley". The Cormorant bioherm has an open framework with high inter- and intra-particle porosity (Choquette and Pray, 1970) but the "round valley" bioherm contains much carbonate mud within the shelly framework.

The reef at Ship Cove is black in color and composed of limestone. It grew upon a stromatolitic mound 30 cm thick, composed of hemispheroidal heads of internally structureless, black micrite (Plate 54). The mound overlies gray to black mudstones which contain the bryozoa, *Batostomella* and the pelecypod, *Leptodesma dawsoni.* The bioherm has a maximum thickness of 35 m at Cormorant rock but thins irregularly and rapidly southwestward beneath a thick gypsum deposit that overlaps the bioherm. Northeastward, the bioherm changes laterally to a biomicrite containing many complete brachiopods and resembling the argillaceous dolomitic mudstones of "round valley".

The bioherm on the North Branch River is approximately 7.5 m high with a steep western margin. It lies directly on dark gray mudstones which overlie red and green siltstones and is onlapped and capped by white, gray and black, laminated, selenitic gypsum. The brown dolomitic bioherm consists of a core of partly brecciated, skeletal peloid packstone with low porosity, surrounded by an outer, rubbly, vuggy, fossiliferous zone. Branching bryozoa *Batostomella*, brachiopods

(Plates 55 to 56) gastropods, foraminifera, algal lamination, some oncolites and a few ostracods occur in the bioherm.

A complex history of sedimentation and cementation affected the "round valley" bioherm. Brown, fibrous, radiating cements up to 2 mm thick were precipitated (1) in brachiopods, (2) on the outside of, but not in, zooecia pores of bryozoa and (3) within reef spaces of both the core and rim of the bioherm (Plates 55 to 56). The cement postdates the early infiltration of peloid packstones into the brachiopods and the formation of a dark sheath, possibly of algal origin, that encloses the outer surfaces of the bryozoa and beneath which the bryozoa were locally micritized. In some bryozoa, fine spar-filled tubules can be discerned beneath the dark sheath. The cement, however, predates fracture of the shells and deposition of a later clear, blocky spar that filled zooecia and coated fibrous cement in the brachiopods in a manner similar to pendant-like cements (Scholle, 1978). The primary fibrous cement was locally fragmented and recemented by a second generation of fibrous cement which also locally bound the packstone. The remaining chamber porosity in brachiopods as well as breccia and fracture porosity were filled by gypsum.

The history of the bioherm can thus be summarized as follows: 1) growth of reef framework of living brachiopods and bryozoa; 2) algal encrustation and micritisation of bryozoa when the organisms died; 3) **in situ** generation of peloid mud by reef organisms or trapping of mud by reef framework; mud infiltrated some shells; 4) precipitation of brown fibrous cement precipitation within brachiopods, around bryozoa and in reef spaces; 5) the cement was broken and recemented in places; mud was deposited over cements and in turn sealed by later cement; 6) clear, blocky spar filled bryozoa zooecia and the remaining porosity of brachiopod chambers; and finally 7) gypsum was precipitated in reef spaces when the overlying sulfate deposit was laid down.

Interpretation of lithofacies F: The various carbonates of the Codroy Road Formation were deposited in a number of different environmental settings during marine transgression of the subbasin. The black, bioturbated, fossiliferous, dolomitic mudstone and fine dolomites were probably deposited in quiet, muddy, lagoonal areas. The sparse, dwarfed fauna of gastropods and bivalves perhaps indicate that such areas were slightly hypersaline. Carbonaceous laminae in many beds suggest that subtidal algal mat bound the muds in the lagoons. The lagoons were probably not deep because suspended mud in the waters would limit light penetration and restrict algal activity.

The bioherms apparently formed as isolated organic buildups in many places throughout the basin. Small algal mounds typified by obscure internal structure such as occur in thrombolites (Aitkens, 1967) of subtidal settings, formed a hard, elevated substrate upon which some bioherms were constructed as in the Cormorant limestone. No such substrate however, is apparent at the "round valley" reef. The bioherms probably grew to an elevation of several to tens of metres above the surrounding lagoon floor, as both the "round valley" and the

Cormorant bioherm thin abruptly beneath overlying gypsum beds. The Cormorant bioherm passes both southeastward and westward into lagoonal, brachiopod-bearing muds. The open framework and low mud content of the Cormorant bioherm suggests that it was built in a relatively high-energy setting. A lower energy setting is envisaged for the "round valley" buildup which is rich in mud.

The fibrous cements in the "round valley" bioherm compare to submarine cements of modern reefs (Land and Goreau, 1970; Friedman et al., 1974; James et al., 1976). Varying thickness of the fibrous cements, the interlayering of mud and cement and the recementation of fragmented cement all point to cementation over a prolonged time interval.

The black massive dolomites, like the Black Point limestone, give little information to aid in their interpretation. They are poorly stratified and include evidence of algal binding but are generally devoid of fossils. Rare ostracods, calcispheres and polychaete and/or serpulid worms (Johnson, 1971) suggest a hypersaline environment (Marszalek, 1975; James, 1979). Fibrous cement in the worm tubes may reflect early marine lithification. Diagenesis of the original carbonate mud due to hypersalinity may explain the presence of radiating diagenetic fabrics replacing dolomite.

The vuggy, brecciated, limonitic carbonate deposit on the Codroy coastal section, however, is fossiliferous and perhaps was originally a bioherm or skeletal-rich mud mound. The thickness of the Black Point limestone and its absence in other exposures in the Codroy lowlands argues for a mud bank or mound which may have formed southeast of a skeletal barrier. Fine carbonate mud, stabilized by algal binding, accumulated in the lee of this barrier. Salinity generally was higher in the back-barrier environment and hence restricted the fauna to a few salinity-tolerant molluscs, ostracods and serpulid worms. It also probably led to dolomitization of the carbonate mud and formation of radiating cements and diagenetic fabrics.

Paleontology, age and correlative deposits of the Codroy Road Formation

A marine macrofauna from the Cormorant limestone of the Codroy Road Formation are listed in Table 6. Conodonts (von Bitter and Plint-Geberl, 1982) include Taphrognathus n.sp. A., Cavusgnathus regularis type, ?Bispathodus sp., Spathognathodus n.sp., A. and S. campbelli. They were recovered from the Cormorant limestone and from black limestones of the northern part of the Codroy coastal section and in the section immediately south of and stratigraphically underlying the Black Point limestone (von Bitter and Plint-Geberl, 1982). The conodont fauna is included in the Taphrognathus zone. A restricted fauna characterized by Cavusgnathus windsorensis occurs in the Black Point limestone and was assigned to a third and younger conodont zone, the Cavusgnathus zone by von Bitter and Plint-Geberl (1982). Using this solitary fauna, they correlated the Black Point limestone with the Heatherton limestone of the overlying Jeffrey's Village Member, Robinsons River Formation. This correlation is not accepted here (see discussion in Paleontology and Age, Jeffrey's Village Member). Rather it is suggested the restricted fauna of the

Black Point limestone was environmentally controlled by seawater hypersalinity, the same factor that von Bitter and Plint-Geberl (1979, 1982) claimed as the principal ecological control for C. windsorensis in the Ship Cove Formation.

The Taphrognathus conodont fauna is similar to that recovered from limestone beds low in the Miller Creek Formation of Nova Scotia (von Bitter and Plint-Geberl, 1982), whilst the macrofauna is also dominated by species typical of the same Nova Scotia formation (cf. Moore and Ryan, 1976). These faunas are typical of lower subzone B of the Windsor Group (Bell, 1929; Moore and Ryan, 1976; von Bitter and Plint-Geberl, 1979). Because they are recorded mostly from the Cormorant limestone, which lies at the top of the Codroy Road Formation, it is probable that much of the fine siliciclastic strata in the lower part of the formation lies within Windsor subzone A. This implies correlation of the lower strata with the Vinland and Tennycape Formations of the Minas subbasin of Nova Scotia (Moore and Ryan, 1976). A difference of approximately 1700 m thickness exists between the sequence in the Codroy Road Formation (120 to 300 ?m) and that of the Vinland-Tennycape Formation (2,000 m).

Depositional environment of the Codroy Road Formation

At the close of deposition of the Ship Cove Formation, intertidal carbonate flats were extensively developed in the south and possibly extreme north of the subbasin with offshore conditions restricted to the Fischells Brook area. This paleogeographic zonation apparently continued during the deposition of the Codroy Road Formation as witnessed by spatial distribution of its constituent lithologies. Cyclic successions of gray beds, evaporites and redbeds, with or without limestone, occur in the southeast. They reflect flooding-dessication-progradation of a marginal marine to alluvial plain environment. In the middle of the subbasin, from north of Ship Cove to Robinsons River, gray siliciclastics of subaqueous origin predominate with important deposits of evaporites. These, in turn, pass northwards into evaporites with gray shales and laminated carbonates of probable sabkha and intertidal origin from the area of Flat Bay to the southern edge of the Port au Port ridge.

The structures in the gypsum deposits of the north compare to those of modern evaporite sabkhas in which sulphates grow displacively in intertidal-supratidal carbonate flats. In the central zone, the fine gray siliciclastic sediments with their fine laminations, selenite rafts, halite-crystal pseudomorphs and minor black mudstones were deposited in a narrow, hypersaline lagoon or arm of the sea that was probably at most only a few tens of metres deep. The evaporitic groundwaters in the sabkha flat to the north were supplied by brines from the lagoon by storm flooding (Butler, 1969) and evaporative pumping (Hsu and Siegenthaler, 1969; Hsu and Schneider, 1973). Little evidence is available to construct the history of the lagoon and the evaporites. Nevertheless, the cyclicity in the gray to red siliciclastic rocks, the importance of evaporite deposition toward the top of the Codroy Road Formation and the presence of a shelly, biohermal limestone buildup capped by evaporites generally indicate that changes in water depth, sedimentation rates and salinity must have occurred. Preservation of discontinuity surfaces and of some carbonate beds in the northern evaporite zone also point to acceleration and periodic cessation of evaporite deposition.

In the south, the pronounced cyclicity of the sediments reflects marine flooding that was followed by dessication. Fine alluvium prograded north to impinge upon the margin of the lagoon. This alluvial plain hosted playa lakes and flats in which nodular and crystalline gypsum and halite crystals were deposited. With marine flooding, the alluvial plain was drowned and retreated southeastward. In the expanded lagoon, gray siliciclastics were laid down. As dessication proceeded, restricted smaller lagoons and marginal lakes became isolated from the main lagoon. Deposits of sulfate evaporites were laid down in these small water bodies which may have survived for long periods as they were recharged by storm flooding (Shearman, 1970) or groundwater or brine seepage.

Toward the closing history of the Codroy Road Formation, major floodings brought near-normal marine conditions, allowing a limited fauna to thrive at first on the muddy sea floor and thrombolitic algal mounds to form small highs. Bryozoa-brachiopod biohermal buildups affected by marine cementation studded the basin at these times but were presumably killed off as the salinity increased and gypsum was precipitated subaqueously. Two or three such episodes occurred in the basin, particularly toward the top of the formation. Where bioherms lay close to the basin margin, they possibly formed barriers behind which thick deposits of stratified, structureless lime muds accumulated. The lagoons hosted a very restricted fauna, including serpulid worms, and periodically became hypersaline, resulting in extensive dolomitisation.

Robinsons River Formation

Definition and distribution

The Robinsons River Formation is the name proposed by Knight (1983) for a complex succession of 5000+ m of terrigenous clastic rocks with lesser amounts of carbonate and evaporite strata. The succession had not been previously named or subdivided, although it was assigned to the upper Codroy Group by Baird and Cote (1964) and appears to have been considered partly equivalent to the Woody Head and Woody Cove beds by Bell (1948). The formation derives its name from Robinsons River, which crosses the St. George's Bay lowlands.

The Robinsons River Formation underlies both the St. Georges Bay and Codroy lowlands but the continuity of the succession is broken between the two areas by faulting, folding and the presence of a large tract of Anguille Group strata. The lithologically heterogeneous succession was influenced by the interplay of tectonic setting, climatic conditions and changing depositional environment. Consequently, a variety of sediments have been deposited repeatedly through a great thickness of strata and probably in a time interval of 5 to 8 million years. Rock types also varied with depositional location in the subbasin.

Nevertheless, the formation will be subdivided into four members based upon lithological characteristics and biostratigraphic information. They are in ascending order the Jeffrey's Village, Highlands, Mollichignick and Overfall Brook Members. The first two occur principally in the St. George's Bay lowlands, while the last two are restricted to the Codroy lowlands. Arkoses of the upper part of the Brow Pond lentil are also placed in the Robinsons River Formation; the lower sequence is retained in the Spout Falls Formation of the Anguille Group.

The Jeffrey's Village Member conformably overlies the Codroy Road Formation. It is best exposed in the St. George's Bay lowlands particularly on the coast and along some of the rivers that cross the lowlands. It is, however, also known from the "round valley", Codroy lowlands. The basal beds of the formation are found in a slightly overturned syncline on the coast near Millville in the Codroy Valley. Float recovered along Brooms Brook also suggests basal beds may be present in tight synclines that occur in the Anguille Mountains.

The basal contact of the Jeffrey's Village Member is placed at the top of the Black Point limestone at Codroy, above the Cormorant limestone and the overlying gypsum at Ship Cove, and at the top of the gypsum located at the railway bridge which crosses Fischells Brook on the west limb of the Flat Bay anticline. The upper contact is placed at the top of the Crabbes limestone and is best exposed at the mouth of Crabbes River, at Robinsons Head, Stinking Cove and possibly Muddy Hole (Fong, personal communication, 1976; Bell, 1948).

The type section of the Jeffrey's Village Member is compiled from a number of incomplete sections which are correlated by means of the Heatherton limestone (Figure 20 on Foldout C). The section begins on Fischells Brook commencing at the railway bridge and continuing to the last exposures 0.7 km from the mouth of the river. The upper part of the member was measured at the coast near Jeffrey's. The two sections are correlated by tracing sink holes associated with gypsum immediately above the Heatherton limestone. The sequence above this limestone marker is also well exposed along the coast from Rattling Brook to Robinsons Head but there it has not been measured.

The Highlands Member, previously called the Highlands sandstone member by Baird (1959), conformably overlies the Crabbes limestone. The type section is located along the coast south of Crabbes River and continues to the youngest beds exposed in the St. David's syncline; the succession then continues beneath the shallow waters of St. George's Bay. Equivalent but undivided strata occur inland east of the Barachois synclinorium (Fong, personal communication, 1976) and a thick sequence of redbeds penetrated in a drill hole at St. Teresa (Amax Exploration, 1976) is also placed in the member.

To date, the Mollichignick Member is known only from the Codroy lowlands where it is named after Mollichignick Brook. The type section (Figure 21 on Foldout C) occurs along the North Branch of the Codroy

River and the Grand Codroy River. The stratigraphic base is not seen and the basal contact, seen 3.2 km north of the community of South Branch, is everywhere a major, northeast trending fault. The section is exposed downstream along the Grand Codroy River as a southeastward dipping monoclinal sequence to the point where the upper contact with the Overfall Brook Member is reached, approximately 750 m northeast of the confluence with Overfall Brook. The Mollichignick Member extends as far southeast as the vicinity of the Codroy Provincial Park, where it terminates against a fault zone trending east-west between Stormy Point and Little Codroy Pond. The member also continues northeast from the type section into the ground between the North and South Branchs of the Grand Codroy River. Here it terminates south of Bald Mountain against an east trending fault system along the North Branch River and also against the Long Range fault to the southeast.

The Overfall Brook Member occupies the core of a southeast plunging, locally overturned syncline that formed adjacent to the Long Range fault. It is terminated against the major fault that is postulated to strike from Stormy Point to Little Codroy Pond.

The type section (Figure 22) is located along Overfall Brook, the tributary stream that lends its name to the member. Exposures are also found in other incised streams northeast of Overfall Brook.

The conformable base of the member is placed at the first thick, continuous succession of arkosic rocks overlying the finer, red and gray beds of the Mollichignick Member. The basal contact is exposed

750 m north of the mouth of the Overfall Brook in the bed of the Grand Codroy River.

Rocks of the Brow Pond lentil that are assigned to the Robinsons River Formation are found in a west-southwest dipping sequence that forms the high plateau near Brow Pond and Big Otter Pond in the northeast corner of the subbasin. The succession overlies a local unconformity in the lentil. The unconformity, mapped using airphotographs, can be traced from Brow Pond south to Big Otter Pond. Contacts with other parts of the Codroy Group and the younger Barachois Group are generally faulted. The Barachois Group may, however, stratigraphically overlie the strata of the Brow Pond lentil north of Fischells Brook.

Thickness

A cumulative thickness of approximately 5000 to 6200 m is likely for the Robinsons River Formation. The two lower members in the St. George's Bay lowlands comprise 2400 to 3400 m of the succession, while a thickness of 2500-2700 m is represented by the upper members in the Codroy lowlands.

The Jeffrey's Village Member is approximately 1400 m thick in the type section. The member may thicken to 2000 to 2100 m in the vicinity of salt deposits that occur southwest of the Flat Bay anticline (Hooker Chemical Corporation, 1968b, 1971). A basin, filled with 5000m of dominantly Codroy Group strata, lies beneath St. George's Bay (Spector, 1969; Golden Eagle Developments Ltd., 1975). The presence of a possible salt structure in the basinal deposits suggests that a part of the sequence belongs to the Jeffrey's Village Member.

The type section of the Highlands Member was measured at 884 m with an additional 200 to 500 m likely offshore (Bell, 1948; Baird, 1959).

The succession of the Mollichignick Member is calculated from the type section to be at least 2275 m thick. The Overfall Brook Member is at least 345 m thick in the type section.

General lithology

The succession found in the Robinsons River Formation is described for each member and is followed by detailed descriptions of lithofacies that occur in the formation. The successions found in the St. George's Bay and Codroy lowlands are illustrated in Figures 20 and 21 respectively. The characteristics and relative importance of lithofacies in each member are tabulated in Table 7.

Jeffrey's Village Member

The Jeffrey's Village Member consists of red and gray shales, mudstones, siltstones, sandstones and conglomerates interbedded with carbonates and evaporites. The latter include anhydrite, gypsum, halite and potassic salts.

Sedimentary rocks of the Jeffrey's Village Member can be divided conveniently into two parts, which are separated by the Fischells limestone (Figure 20). Below the limestone, the succession contains dominantly drab-colored, fine siliciclastic rocks, some evaporites and lesser redbeds. The upper sequence consists of red siliciclastics with several carbonate units and minor evaporites.

The lower sequence from Ship Cove southwest to Codroy commences with fine redbeds with some carbonates which are brecciated (Codroy breccias, Bell, 1948). In the north, near Fischells Brook, however, the lower sequence is dominated by thin bedded, gray, green, black and brown mudstones, and siltstones with some fine green-gray sandstones and fine redbeds. They comprise mostly lithofacies N, O, P, and Q and lesser amounts of lithofacies M, B and A. Massive to finely laminated, gray, green and black mudstones and green-gray, ripple cross-laminated siltstones dominate thick sections of the lower sequence. They are associated with two major units of green-gray, fine grained sandstones that are rich in green mudclasts and large trough crossbeds. The rest of the lower sequence is composed of brown, structureless silty mudstones and ripple cross-laminated and laminated siltstones; very fine sandstones are also present intercalated with finely laminated, varicolored mudstones. Small halite pseudomorphs are common in some mudstones and siltstones; dessication structures also occur. Rippled sandstones, bar-shaped sandstone bodies, some red siltstones and planar crossbedded sandstones are also present.

The evaporites in the lower Jeffrey's Village Member consist of anhydrite, gypsum, halite, and some carnallite, sylvite and polyhalite (Hooker Chemical Corporation 1968a, 1972, 1973). Potassic salt horizons occur at the top of the 390 m thick Fischells Brook salt deposit. The salt is relatively free of clays but contains variable amounts of anhydrite and gypsum. The salt deposits at Robinsons and St. Fintan's are well bedded and contain many interbeds of fine gray and some red siliciclastics. Two salt horizons, separated by gray shales, occur in the Robinsons deposit. Potassic salts are distributed at several levels within the intercalated salt and mudstones that form the St. Fintan's and Robinsons salt.

White, massive and selenitic gypsum (Bell, 1948) is exposed near Plaster Cove. It lies near the base of the evaporite section about 100 m beneath the main salt sections.

Above the Fischells limestone, the Jeffrey's Village succession is approximately 785 m thick. It includes greater than 50% fine beds composed of red, structureless siltstones and red, calcareous, shaly siltstones (lithofacies A and K) which may contain mudcracks, halite pseudomorphs and some caliche. The fine redbeds are interbedded with sheet deposits of fine grained sandstones (lithofacies B and C) which generally display planar stratification and ripple cross-lamination. Thicker red sandstones (lithofacies D) contain crossbedding and planar stratification; massive to crossbedded conglomerates and pebbly sandstones (lithofacies E) are interbedded with the ubiquitous red siltstones. The latter contain significant caliche limestones in the middle of the sequence. Pebbles in the conglomerate (see Table 8) were derived from the Cambro-Ordovician platformal sequence north of the subbasin and from granites and silicic volcanics like those of the

Topsails Igneous Complex to the southeast of the subbasin. Overall, the succession is sandier in the stratigraphic interval from the Fischells limestone to a point 130 m above the Heatherton limestone. For the next 150 m the succession is dominated by red siltstones and thin, fine grained sandstones but gradually coarsens upward not only towards the top of the member but apparently also northward and eastward over the same stratigraphic interval.

A variety of carbonates (lithofacies R), fossiliferous, bioturbated and mildly evaporitic gray shales, rippled and planar-laminated siltstones and sandstones (lithofacies M) and very minor gypsum and celestite (lithofacies S) are intercalated in the redbeds. Some red fine sandstones and siltstones with abundant ripple marks, local bioturbation and planar stratification lie immediately above or are associated with the carbonates (Figure 27; JVL-2, Figure 31).

The carbonates in the Jeffrey's Village Member are buff weathering, argillaceous and dolomitic limestones or gray, purer limestones. Lime mudstones, fossiliferous and peloidal wackestones and packstones, algal and stromatolitic limestones and some oolitic grainstones are all represented. Secondary dolomites and calcretes are also common. The carbonates decrease in thickness upward as they change from skeletal packstones and lime mudstones and shales in the lower units to oolite and stromatolite-dominated upper units. Thin evaporites (gypsum zone D of Bell, 1948) occur with the algal carbonates of the Heatherton limestone. This unit has been extensively replaced by red dolomite. Fossiliferous and oncolitic, clean gray limestones interbedded with gray shales form the Crabbes limestone, i.e. the top of the member.

Unlike the lower evaporitic succession, the upper, dominantly alluvial sequence appears to be fairly uniform in thickness in the St. George's Bay area. Carbonate strata in the "round valley" area suggest the upper unit extended into the northern part of the Codroy lowlands.

Highlands Member

The upward coarsening of the red fluviatile rocks in the top of the Jeffrey's Village Member culminated in the deposition of a 1200+ m thick sequence of red, minor gray and some yellow sandstones and red siltstones in the Highlands Member of the St. David's syncline. Conglomerates and argillaceous, pebbly sandstones were laid down in time-equivalent strata to the east and north (Fong, personal communication, 1976). Brown-red conglomerates and pebbly sandstones also compose the St. Teresa drill hole (Amax Exploration, 1976).

The succession in the St. David's syncline consists dominantly of repetitive fining-upward sequences, 5 to 15 m thick, composed of intraformational conglomerates, crossbedded and planar laminated sandstones (lithofacies D) and red siltstones (lithofacies A) with some caliche (lithofacies H). The sandstones are generally friable and calcareous. Green reduction spots are particularly common in the sandstones. Most caliche limestones are nodular; four caliche limestone beds, 90 to 210 cm thick, occur in the middle part of the member. Caliche and red siltstones were reworked into channel-bound intraformational conglomerates (lithofacies G). Some red sandstones in the succession may have an aeolian origin.

Coarsening-upward sequences of green to reddish-green shales, siltstones, and fossiliferous, bioturbated, rippled and laminated sandstones occur at the base of the member immediately above the Crabbes limestone (Figure 27). Approximately 200 to 310 m above the base of the Highlands Member in the type section, two thin units of clean, white to green, current- and wave-rippled sandstones and siltstones (lithofacies M) are interbedded with wavy bedded, fossiliferous, laminated, mudcracked gray limestones.

Mollichignick Member

The 2300 m succession of the Mollichignick Member (Figure 21 on Foldout C) is composed mostly of red siltstones (lithofacies A), red to gray micaceous sandstones (lithofacies B) and stratified sandstones (lithofacies C). Also present are ungraded and fining-upward sequences consisting of thick gray sandstones (lithofacies D) intercalated with red siltstones. Argillaceous and arkosic pebbly sandstones (lithofacies E) occur interspersed in the succession with many of the other lithofacies and form thick basin-fill sequences close to the southeast margins of the subbasin. Units of gray, lacustrine mudstones, carbonates and micaceous sandstones and siltstones (lithofacies H and I) are important contributors to the lower 1000 m of the Mollichignick Member. Marine carbonates, shales and sandstones, which are characterised by thin coarsening-upward sequences, some shelly fossils, ripple-marks and bioturbation (lithofacies L, M, Q, and K) are found in the middle of the member (1200-1700 m above base).

The lowest part of the member is dominated by a series of coarsening-upward megasequences, 45 to 220 m thick. They are composed of gray beds (lithofacies H and I), red siltstones (lithofacies A) gray and red sandstones (lithofacies C) and are capped by pebbly and argillaceous, arkosic sandstones (lithofacies E). Together these megasequences form a thick, upward-coarsening, basin-fill sequence.

Above the megasequences, thick gray sandstones (lithofacies D) and caliche-bearing red siltstones (lithofacies A and F) become widely developed in the Codroy lowlands. Lithofacies C and E (planar-stratified sandstones and pebbly sandstone and conglomerate) occur stratigraphically higher in the member toward the centre of the subbasin, whilst lithofacies E conglomerate and pebbly sandstones were laid down at the margins. In the middle of the succession, shales, siltstones and rarer carbonates (facies A, K, L and M) dominate the sequence.

Overfall Brook Member

The Overfall Brook Member (Figures 21 and 22) is composed mostly of red, pink and brown, thick-bedded, massive and crossbedded, pebbly and arkosic sandstones and grits, argillaceous sandstones and minor conglomerates. The coarse sequence in the lower part of the member is interrupted at 5 to 30 m intervals by units of fine, gray mudstones, siltstones and pebbly mudstones (Facies H and J) together with some red siltstones and sandstones. Above this, the fine sediments are generally infrequent, and decrease upward concurrent with an increase in sand- and pebble-sized grains (Figure 22).

Description of lithofacies

Eighteen major lithofacies are defined in the Robinsons River Formation (Table 7).

(A). Siltstone lithofacies

Description of lithofacies A: This lithofacies is composed of dominantly red-colored, structureless, hackly-weathering, siltstones or intercalated structureless and current-laminated siltstones (Plates 57 and 58). It groups together indiscriminately all lithologies of clay to silt grade. The facies, which occurs in units 20 cm to 14 m thick, is most abundant in the Jeffrey's Village Member, forming more than 60% of some parts of the succession; it is also an important element in other members.

The massive siltstones are generally uniform, poorly-sorted deposits that exhibit some crude bedding and faint lamination. Current-deposited siltstones, which are 5 to 15 cm thick, are intercalated both sharply and gradationally within the massive siltstones. They have a coarse silt grain size and exhibit both flat and cross-lamination. Mudcracks, plant rootlet impressions and caliche nodules are preserved locally. In the Mollichignick Member, the rootlets form a creeping, spidery, open network across bedding surfaces.

Halite pseudomorphs are common in mudcracked siltstone beds of the Jeffrey's section of the Jeffrey's Village Member. They are preserved as cubes, irregular cubes, and hopper pyramids, 0.2 to 5 cm in size. The present composition of the pseudomorphs is carbonate, siltstone, granulose and porous gypsum, or layered gypsum and siltstone. Preferred corner growth (Shearman, 1978) and interference of sediment (Handford and Moore, 1976) produced skeletal arms up to 5 cm long projecting from crystal corners. Arching of sediment over projecting corners of some crystals also occurs.

A number of discontinuous beds, 1 to 3 cm thick, of pink, fibrous gypsum also occur in gray and red siltstones of the Jeffrey's Village Member. The layers are locally nodular and are enterolithically folded (Shearman, 1978).

Interpretation of lithofacies A: The fine red sediments of this lithofacies are interpreted to be floodplain deposits. (Allen, 1965a; Collinson, 1978a). Where associated with thick channel sandstone (Figures 23 to 25, Foldout D), the siltstones were laid down as vertical accretion deposits following overbank flooding of low-lying areas between channels. The crudely-bedded siltstones were deposited from suspension, and the ripple cross-laminated siltstones were deposited by gentle currents flowing in the lower flow regime (Harms and Fahnestock, 1965; Simons et. al., 1965; Southard, 1975). Dessication of the floodplain siltstones was common. Spidery, creeping rootlet patterns suggest vegetation flourished locally; nodular caliche formed in soil horizons. Both caliche (Gile et. al., 1966) and the spidery plant rootlet systems (Sargaent, 1975) are indicative of semiarid climatic conditions.

Where the siltstones are interbedded predominantly with fine sandstones of facies B and locally with marine carbonates (Figure 20), a distal position on an alluvial and/or coastal plain is envisaged. In this environment the muds and fine sandstone sheets were deposited by small streams, sheet floods and possibly by aoelian processes.

Halite pseudomorphs and gypsum layers in the facies in some sections of the Jeffrey's Village Member suggest that some of the siltstones accumulated locally in playas. Features such as enterolithic folding of gypsum layers, interlayering of sediment and evaporite in halite pseudomorphs, arching of sediment over the corners of the halite crystal corners and growth of skeletal arms out of halite crystals (Smith, D.B., 1971; Handford and Moore, 1976; Shearman, 1978) indicate both evaporite phases formed mainly displacively in brine-saturated muds.

(B) Fine sandstone lithofacies

Description of lithofacies B: Facies B consists of argillaceous and micaceous, gray and/or red, sandstones that are fine or very fine grained. The facies occurs in all but the Overfall Brook Member. Either it is interbedded with just facies A siltstones (Sections A-D, Figure 23) or else it forms sequences with both facies A siltstones and graded sandstones of facies D (Figure 23, Sections A to E; Figure 24, Sections E; Figure 25, Sections A to C).

Sandstones associated only with facies A siltstones are commonly graded, very fine grained deposits, 20 to 100 cm thick. They form sheets that lie erosively or sharply upon red siltstones (Plate 58) and commonly contain layers of sand-sized mudchips (Figure 23, Section A). Ripple cross-lamination occurs with rib and furrow, and planar lamination which is associated with parting lineations. Shallow to deep (3 to 36 cm) scours, some filled by red siltstone, cut through some of the sheet sands. Mudcracked siltstone partings occur between beds and toward the top of sandstone beds.

Fine sandstones associated with graded sandstones of facies D are either graded or ungraded, poorly sorted deposits that have sheet, lenticular and rarely bar-shaped forms (Plate 59). The sands are characterised by basal and internal scours, climbing ripple-drift (Plate 60), convolute bedding, and lenses of structureless sand; planar stratification and crossbedding are also present. Mudcracked, mudstone partings and flat, coarsely laminated, silty mudstone beds, 3 to 15 cm thick, occur between sandstone beds.

Paleoflow direction of ripple-drift in sandstones of the second association is generally perpendicular to that of crossbeds of facies D sandstones.

Interpretation of lithofacies B:The fine sandstones are interpreted as deposits of small streams and crevasse splays, deposited in distal parts of the alluvial plain or near river channels.

The graded sheet sandstones interbedded with facies A siltstones in the Jeffrey's Village Member are probably deposits of shallow, ephemeral stream channels that crossed the distal alluvial plain. Small scale, linguoid, lunate or cuspate ripples (Harms, 1975) forming cross-laminated sands migrated along the channels under lower flow regime conditions (Simons, et al., 1965). Ephemeral deposition is indicated by red siltstone plugs and mudcracked siltstone parting within the sandstones.

Fine sandstones associated with facies D sandstones have characteristics that compare with those of channel levees or crevasse splay deposits (Reineck and Singh, 1975; Ray, 1976; Collinson, 1978a). The predominance of climbing ripple-drift in many of the sheet sandstones suggests that abundant fine sediment was rapidly deposited from suspension during overbank flooding (McKee, 1965). Interbeds of flat, coarsely laminated, silty mudstone and dessication structures in both mudstone interbeds and drapes suggest that thick sequences composed of these lithofacies accreted over many flood-cycles of overbank sedimentation.

The bar-shaped sand deposits, that are also characterized by climbing-ripple laminations, are probably crevasse splays deposited near the point at which flood waters breached a levee.

(C) Planar-stratified sandstone lithofacies

Description of lithofacies C: This lithofacies forms a particularly important element of the Mollichignick Member but also occurs in the Jeffrey's Village Member. The facies is formed of fining-upward sequences of gray or red sandstone and red siltstone (Figure 23, Sections B and C; Figure 25, Sections D and E).

In the Jeffrey's Village Member, buff to red, fine and very fine sandstones, 10-50 cm and rarely 200 cm thick, are intercalated with red siltstones. Flat planar lamination with parting lineations, some climbing ripple-drift, and sharp flat bases and tops typify the sandstones.

Dominantly gray, fine- to very fine-grained sandstones rich in mica and fine carbonaceous plant detritus compose this lithofacies in the Mollichignick Member. The sandstones occur in units 1 to 4 m thick in two facies associations. The first association (Figure 25, Section D) consists of one or more sandstone units interspersed every 4 to 10 m in red siltstones. In the second association (Figure 25, Section E), stratified sandstones are separated by only 20 to 200 cm of siltstone, and many form megasequences up to 130 m thick.

Bases of sandstone beds in the Mollichignick Member are generally sharp and planar or locally irregular (Plate 61), but in some instances they are gradational with the underlying siltstone. The sandstones are composed almost exclusively of thin stratification and lamination that is either planar, or broadly undulating (Plate 61).

Parting lineations are generally absent, possibly because of the high mica content. Bedding is locally inclined where it conformably overlies steeply inclined, generally planar scours. The scours truncate underlying thin beds and pass out into slightly discordant planar surfaces within the main body of the sandstones.

Rare crossbedding occurs near the bases or tops of the sandstone units. Elliptical scours, 1 to 3 m wide and 8 to 30 cm deep, are filled symmetrically by thin stratification; complete geometry of the crossbeds is uncertain due to the nature of the outcrops.

Ripple cross-lamination and climbing ripple-drift of types A and B (Jopling and Walker, 1968) plus low amplitude sinusoidal lamination occur toward the top of some units. The top sandstones, which are red, pass up into red siltstones which also display crude planar lamination and local scour and fill. Coarse, tubular, silt-filled molds (Plate 62) are common in the tops of sandstone units, and spidery plant rootlets occur in overlying laminated siltstone.

Interpretation of lithofacies C: The sandstones of this facies, although they fine upward, are not characteristic of classical, fining-upward fluvial cycles, typified by channel scour bases, abundant trough crossbedding and basal lag of mudclasts (Allen 1964a, 1965 a, and b). Facies C sandstones are sheet-like and characterized by horizontal thin stratification and lamination overlying only locally erosive bases. The geometry and bedding compares to that found in crevasse splay (McKee et al., 1967; Coleman, 1969), sheetflood or ephemeral, low-sinuosity stream deposits (Williams, 1971; Picard and High, 1973; Tunbridge, 1981a and b).

Although parting lineation is rare, the Mollichignick sandstones were probably deposited from currents flowing in the upper flow regime (McKee et al., 1967). Abundance of micas, especially in the Mollichignick sandstones, suggests that the fine sandstones were deposited rapidly from suspension with no time for mineral sorting or alignment. Rapid deposition of sand during the late waning stages of flood (McKee et al., 1967) is indicated by climbing ripple-drift (McKee, 1965) at the tops of some sandstone units (see also Williams, 1971). The presence of low-angle scour surfaces within the deposits suggests a number of flood surges which were locally erosive.

The thick facies C deposits of the Mollichignick Member were probably sheetwash or shallow ephemeral stream deposits generated on the lower slopes of alluvial fans by flashfloods. (Heward, 1978b; Hardie et al., 1978). Sediment from the inner slopes of the alluvial fans was reworked (Blissenbach, 1954; Hooke, 1967) and redeposited at the toe of the fan or on the adjacent alluvial plain, perhaps as a sandflat apron (Hardie et al., 1978). Tunbridge (1981a and b) showed the importance of a similar facies in redbeds of the Old Red Sandstone of Wales and southwest England. He concluded that the deposits formed in low-sinuosity sand-bed channels. These merged downslope into silty sheet floods of an extensive alluvial plain that in turn was bordered by a muddy floodplain. He drew an analogy to the geomorphology of the Eyre Basin of South Australia.

Thinner sand sheets of the Jeffrey's Village Member formed when flood-stage rivers carrying abundant fines in suspension escaped the confines of their channels. This occurred either by levee breaches (Allen, 1965a) or when the dimensions of channels were inadequate to confine the magnitude of floodwater and a general overflow of the banks occurred (McKee et al., 1967; Baker, 1977).

D. Thick, graded and ungraded sandstone lithofacies

Description of lithofacies D: Fining-upward, ungraded, and some coarsening-upward sandstones, mostly 0.5 to 13 m thick, form important parts of the Jeffrey's Village, Highlands and Mollichignick Members (Figure 23, Sections D to G; Figure 24, Sections B to F; Figure 25, Sections A to C). Multistory sandstone sequences up to 20 m thick are also common. These are composed of two or more fining-upward or ungraded sandstones separated by major scour surfaces, or coarsening-upward deposits. The latter consist of red shaly to massive siltstone grading up into interlaminated siltstone and sandstone or intraclastic conglomerate (Figure 23, Sections E to G; Figure 24, Sections D, E and F).

Fining-upward sandstones of lithofacies D consist typically of a basal scour overlain by intraclastic and pebbly sandstone or locally conglomerates that are in turn overlain by sandstones (Plate 63). Channel geometry was noted in some units in the Highlands Member.

Coarse to very coarse grained sandstones enclosing small-diameter, red and green mudclasts, caliche pebbles, extrabasinal pebbles, and some coalified plant debris, form basal deposits 20 to 300 cm thick in the Jeffrey's Village and Highlands Members. They are generally absent or just a few centimetres thick in the Mollichignick Member. The deposits are typified by internal scours, crude to well defined planar stratification and some large, trough crossbeds 20 to 40 cm and locally 1.5 to 2 m thick.

Above the basal deposits, graded, very coarse to medium or fine grained sandstones consist predominantly of large, trough crossbeds. The crossbeds are mostly 10 to 40 cm thick but may reach 60 to 200 cm thick. The size of trough cross-stratification generally decreases upward, as does grain size. Units then pass up into, or intercalate with thinly stratified or laminated layers and wedges, that are 1 to 3 m thick, and carry current lineations. In some units (Figure 23, Section E; Figure 24, Section A, D and E) planar stratification dominates the sandstone units.

Some trough crossbeds lie within channels or form hummocky ridges and depressions at the top of some sandstone units (Figure 24, Section E). An abandoned, siltstone-filled channel occurs 80 m above the base of the Highlands Member.

Ripple cross-lamination occurs near the top of units but is generally rare in all but the Mollichignick Member. Planar cross-stratification is also mostly restricted to sandstones in the Mollichignick Member. Here it occurs near the top of units as small, multiple (5 to 15 cm thick) sets, or solitary, large (40 cm thick) sets composed of coarser pebbly detritus.

Large and small scale convolute deformation of both crossbeds and planar stratification is common and small scale sedimentary faults occur in planar stratified sandstones of the Highlands Member.

Not all fining-upward units are simple gradations of grain size and sedimentary structure up through the units. In one unit in the Mollichignick Member (Figure 25, Section B), there occurs a large channel, 200 cm at its deepest point and more than 19 m wide. It is scoured into previously deposited, equally thick, trough crossbedded sandstone which overlies its own basal scour. The channel, which trends 160^{o}-340^{o}, was infilled laterally by three cosets of southwestward dipping epsilon cross-stratification (Allen, 1963), each bounded by discontinuity surfaces. The final channel is filled by slightly asymmetric cross-stratification which mimics the final channel shape. The channel-fill and the earlier cross-stratified sandstones are both capped by trough crossbedded and planar stratified sandstones beneath red siltstones.

Ungraded and coarsening-upward sandstones of lithofacies D form beds 1 to 6 m thick (Plate 64). The sandstones which are locally pebbly and intraclastic commonly occur in multistory sequences characterized by variable grain size and arrangement of sedimentary structure. In the Highlands Member for example, the sandstones are rich in intraclasts and red siltstone layers and lenses. Most sandstones begin with a scoured base, which in some instances has undercut and pried up wedges of underlying red siltstone. Large trough and planar crossbeds are common. Planar cross sets are up to 60 cm thick, but cosets of smaller, planar crossbeds, 5 cm thick, are also common. Large trough crossbeds, 40 to 130 cm thick, are abundant in the sandstones of the Highlands Member (Figure 24, Section F). Units that are planar stratified are regularly interlayered with those that are cross stratified. Wavy-laminated, sandy siltstones may divide up multistory sandstones, the siltstones grading up into overlying sandstones (Figure 23, Section F).

An ungraded sandstone unit of a different character was noted in the Jeffrey's Village Member (Figure 23, base of Section D) along Robinsons River. It consists of a 120 cm sequence of green-gray, intraclastic fine sandstone beds that are 20 to 50 cm thick, and are separated by 6 to 15 cm beds of red mudcracked siltstone. Above a basal scour, sandstone beds consist of 4 to 20 cm thick planar crossbeds and overlie planar to locally irregular internal scours. Red mudchips are concentrated on lower foresets and above the scours.

Coarsening-upward sandstones are rare except in the Mollichignick Member (Figure 25, Section C), where planar crossbedded, pebbly, very coarse grained sandstones overlie trough crossbedded and planar stratified, medium grained sandstones.

Interpretation of lithofacies D: The sandstones of lithofacies D are interpreted as deposits of river channels.

The fining-upward sequences of the Jeffrey's Village, Highlands and Mollichignick Members are comparable to classical fining-upward sequences of meandering river channels (Allen, 1964a, 1965a, 1970a; Visher, 1972). They are the response of sedimentation to active migration of a meandering river channel and lateral accretion of a point bar on the inner bank of the meander bend. Gradual upward change of grain size and sedimentary structure in an ideal cycle occurs as flow conditions vary during the flood cycle and water depth becomes shallower over the point bar.

The pebbly and intraclastic coarse sandstones that lie upon the basal scour were laid down as lag deposits in the deepest part of the channel during the high stages of river flood. The deposits accumulated in scour pools (Leeder, 1973a) and by lateral accretion along channel thalweg (Allen, 1964a). Large crossbeds formed within megaripples at the base of the point bar (Harms et. al., 1963; Harms and Fahnestock, 1965) or by a process of scour and fill (McGowen and Garner, 1970) along the channel floor.

Deposits of the point bar proper include crossbedded and planar-stratified sandstones that overlie the basal lags. Such structured sands are common within modern sandy point bars (Harms et al., 1963; Harms and Fahnestock, 1965; Steinmetz, 1967; Shelton and Noble, 1974) and in sandstones interpreted to represent ancient point bars (Allen, 1964a, 1965a, 1965b, 1970a; Moody-Stuart, 1966; Allen and Friend, 1968; Leeder, 1973a). Trough crossbeds were deposited by migrating megaripples in the upper part of the lower flow regime (Simons, et al., 1965), whilst planar stratification with parting lineation was deposited in the upper flow regime (Simon, et al., 1965; Harms, 1975). Laterally extensive, thick deposits of planar stratification, such as occur in some of the facies units in the Highlands Member, have been noted in other ancient channel deposits like the Tugford cyclothem (Allen, 1964b). Such stratification is also documented at higher levels of the inside of modern sandy point bars (Harms et al., 1963; Harms and Fahrestock, 1965) and is extensively developed in a point bar of a low sinuosity reach of the Cimarron River (Shelton and Noble, 1974). Although thick planar stratification is also common in flash-flood generated sandy crevasse splays (McKee et al., 1967; Tunbridge, 1981a), a meandering channel environment is suggested for this lithofacies because of the basal scours, locally with channel shapes, and their overlying lag deposits.

Ungraded and coarsening-upward sandstones that occur in the Mollichignick Member deviate from the classical fining-upward sequences of Allen (1965a). However, they are still interpreted as deposits of meandering river channels because of the thick siltstones with which they are associated. Jackson (1978) recently showed that deposits of meandering rivers have a wide spectrum of characteristics that may produce sequences deviating from those of the classical meander cycle. Sandstone sequences in the Mollichignick Member are dominated by trough crossbedding, but include near the top of some sequences sets of planar cross-stratification, which may be composed of pebbly sandstones. The sequences closely resemble overall vertical profiles of coarse grained point bars of meandering rivers (McGowen and Garner, 1970; Jackson, 1975, 1976). Planar crossbeds at the tops of these profiles developed in chute (McGowen and Garner, 1970) or scroll bars (Jackson, 1976) associated with chutes that traversed the top of the point bars during flood stage.

Braided-stream deposits are probably represented by the ungraded or coarsening-upward, pebbly and intraclastic sandstones of both the Jeffrey's Village and Highlands Members. Abundant red siltstone layers and plugs in the succession suggest ephemeral or fluctuating flow typical of rapidly switching braided-stream channels. Frequent reworking of both the sandstones and the adjacent floodplain deposits is indicated by scours, caliche pebbles and mudclasts, as well as the partial erosion of silt plugs (Allen, 1965a; Miall, 1977).

There is a close association in the Fischells Brook section (Figure 20) of these braided-stream deposits with some marine carbonate and shale units of the upper part of the Jeffrey's Village Member. This suggests that some of the braided rivers discharged into shallow inland seas after traversing relatively narrow floodplains. Caliche layers immediately beneath and capping some of the channel sandstones are evidence of breaks in sedimentation.

(E) Pebbly, arkosic sandstone and muddy sandstone lithofacies

Description of lithofacies E: Lithofacies E is developed near the margins of the subbasin, particularly along the Long Range fault where it forms at least three important sequences. These include (1) the Brow Pond lentil (Fong, 1976a and b) in the northeast corner of the subbasin near Steel Mountain, (2) a basin-fill sequence (Heward, 1978a) forming about 1300 m of the Mollichignick Member in the hills between the North and South Branches of the Grand Codroy River, and (3) a megasequence at least 344 m thick in the Overfall Brook Member (Figure 22). Other thick sequences of the facies are probably present to the southeast of the Barachois synclinorium in rocks laterally equivalent to the Highlands and possibly the Mollichignick Members.

Away from the basin margins, argillaceous and coarse arkosic detritus form single beds and sequences, 1 to 30 m thick. These occur in floodplain and lacustrine deposits of the Mollichignick Member in the Codroy lowlands and in floodplain and playa-flat deposits of the Jeffrey's Village and Highland Members, in the northern and eastern parts of the St. George's Bay lowlands. The facies forms a major element in a 2000 m drill hole that penetrates gently dipping strata of the Highlands Member near St. Teresa (Amax Exploration, 1976).

Lithofacies E is composed of white, pink and red, clean arkose and brown-red or gray argillaceous sandstones. The sandstones as a whole are coarse and very coarse grained, poorly sorted and submature (Folk, 1968), and are commonly pebbly or gritty. Conglomerate and some red siltstone are also present. The gray beds are commonly associated with lacustrine deposits of lithofacies H and I in the Mollichignick Member.

Basal scours cut into underlying finer lithofacies and major scours are common within thicker sequences of lithofacies E. Seven types of sedimentary structure have been found above the basal scours. They are (i) massive beds, (ii) crude to well developed planar stratification, (iii) planar cross-stratification, (iv) trough cross-stratification, (v) thin planar stratification and lamination (vi) small scale crossbedding and cross-lamination, and (vii) massive siltstone.

Massive beds are generally rare except in the Flat Bay section of the Jeffrey's Village Member, where they are composed of pebbly grits and conglomerates. The conglomerates, which are similar to facies Gm of Miall (1977) and Rust (1978), are clast- to matrix-supported (Walker, 1975a), and locally contain large intraclasts derived from associated lithofacies. Most of the beds occur immediately above or close to basal erosion surfaces.

Crude to well developed planar stratification occurs in deposits, up to 8 m thick, that are composed of clean or muddy, pebbly sandstones and grits (Plate 65), or rarely of conglomerate. The structure is most commonly developed close to basal erosion surfaces and is poorly to well defined by broad, shallow scours or by undulose layers, 1 to 4 cm thick; the latter are formed by lenticular segregations of coarser particles. The bed type resembles the horizontally bedded versions of facies Gm (Miall, 1977; Rust, 1978).

Planar cross-stratification occurs in sandstones, grits and conglomerates (facies Sp and Gp, Miall, 1977; Rust, 1978), generally above the planar-stratified gravel deposits (Figure 25; Figure 23, Section I).

The crossbeds occur as solitary or multistory sets in sequences 1 to 3 m thick. Most sets are several metres in length and 15 to 40 cm thick, although locally the thickness may reach 110 cm. Straight to curved, graded, 2 - 4 cm thick foreset strata with dips up to 30^{o} overlie sharp, flat scoured bases.

Varying sizes of trough cross-stratification are common in pebbly sandstones and grits (facies St, Miall, 1977; Rust, 1978) (Plates 66 and 67). The sets are solitary or in nested cosets and occur mostly near the tops of sequences. The sets measure 40 to 100 cm wide, 10 to 20 cm thick, and one to several metres in length.

Thin planar stratification and lamination are uncommon, but where it does occur it is generally near the tops of sequences (Plate 67). They are preserved mostly in reddish brown, fine to medium grained sandstones, that are commonly micaceous and argillaceous and form beds 10 to 50 cm thick. The flat, planar stratification (facies Sh of Miall, 1977; Rust, 1978) generally overlies flat surfaces that truncate earlier structures. Parting lineations were not observed.

Small scale crossbedding and cross-lamination (facies Sr and Fe of Miall, 1977; Rust, 1978) occur in fine red sandstones that are interbedded with red siltstones and with fine gray beds of lithofacies

H and J. The sandstone beds are 10 to 25 cm thick, and are composed of single and multiple sets of small scale crossbeds. Rib-and-furrow structure and type A climbing ripple-drift (Jopling and Walker, 1968) also occur. Segregation of coarser grained material into laminae locally reveal horizontal to irregular thin stratification.

Structureless beds of siltstone (facies Fm, Rust, 1978) form beds 10 to 25 cm thick which may contain plant rootlets and mudcracks.

Friable, poorly cemented, clean arkoses are common in the Overfall Brook Member and in the Brow Pond lentil. Units of pebbly sandstone up to 20 m thick are common in the Overfall Brook Member (Figure 22), where they have massive bedding, crude to well developed planar stratification, and planar and trough cross-stratification. Finer grained interbeds up to 4 m thick also occur in the member and these either consist of structureless siltstone or else contain small scale current structures. Pebbles rarely exceed 20% of sandstones and no clear coarsening-upward trends in pebble abundance or size are evident in the Overfall Brook Member. Pebbles in the member consist of crystalline rocks that may have been derived from southeast of the Long Range Fault (Table 8).

Brown-red, argillaceous sandstones, pebbly sandstones and conglomerates typify the marginal basin-fill sequences of the Mollichignick Member. Similiar argillaceous lithologies occur intercalated in the Mollichignick type section which represents the basinward succession in the member. The marginal basin-fill sequence is typified by massive to crude stratification with lesser amounts of crossbedding. Lithofacies E beds and units in the type section of the Mollichignick Member, however, have a greater variety of sedimentary structures.These include lenticular bedding, massive bedding, crude flat bedding, planar and trough crossbedding, scour and fill structures and horizontal lamination. Bar-shaped, crossbedded pebbly sandstone deposits (Plate 68) also occur. Cobbles in lithofacies E units of the type section can reach diameters of 20 cm, as for example in conglomerate outcrops in the bank of the Grand Codroy River, near Limestone Brook, and in the river bed of the South Branch River east of the Trans Canada Highway. Most pebbles, however, are 1 to 5 cm in diameter and consist of metamorphic and granitic rock types such as outcrop today southeast of the Long Range fault (Table 8).

The facies in the Flat Bay section of the Jeffrey's Village Member is composed of conglomerates, pebbly sandstones and sandstones. Beds 60 to 500 cm thick, many cemented by caliche, occur in the lower 200 m of the section. They are interspersed in red shaly siltstones (lithofacies K). In the upper 230 m of the section, the facies comprises sequences 26 to 45 m thick, separated by covered intervals that appear to hide red siltstones. Scours, massive bedding and abundant current bedding typify the facies in the Flat Bay section. Two major scour surfaces occur in the upper 230 m of the section. Both surfaces truncate underlying beds and separate changes of strike and dip in beds above and below the scours.

The size of pebbles decreases upward in the Flat Bay section.

Cobbles, 10 to 15 cm in diameter at the base of the upper sequence, decrease in size to 1 to 3 cm near the top of the section. Pebble composition suggests at least two sources. From the base of the Flat Bay section to 30 m above the base of the upper 230 m thick sequence, the pebbles consist of Cambro-Ordovician carbonates, quartzites, and ultramafics with minor granite and gneiss (Table 8, FB-1). Above the 30 m mark, Cambro-Ordovician carbonates and quartzites are absent. Instead, there is a second pebble assemblage (Table 8, FB-2 and FB-3) which is characterized by schist and phyllite, similar to rocks of the Fleur de Lys Supergroup, and by red and brown, silicic volcanics and granite resembling rocks of the Topsails Igneous Complex (Kean, personal communication, 1980).

Interpretation of lithofacies E: The pebbly and muddy coarse sandstones of lithofacies E possess characteristics of braided stream deposits, recently summarized by Miall (1977) and Rust (1978). The facies accumulated on alluvial fans along the subbasin margin, in fan lobes that prograded onto the adjacent flood plain, and in braided streams that crossed the flood plain.

Variable internal structure in gravels and sands of the facies suggests that they were deposited on bars, and by megaripples in stream channels. The massive pebble beds with crude planar stratification were probably deposited in channels as longitudinal bars (McDonald and Banerjee 1971; Rust 1972; Eynon and Walker, 1974; Smith, 1974; Gustavson, 1974; Miall, 1977; Rust, 1978) as floodwaters lost their ability to carry bed load (Miall, 1977). Deposition would have occurred in scour pools (Smith, 1974), at obstructions in channels or where the channels widened.

Sheet-like deposits of horizontally and crudely bedded gravels and sands resemble sheetflood deposits of modern and ancient alluvial fans (Bluck, 1967; Bull, 1972; Collinson, 1972; Steel, 1974). Such sheetflood deposits form when coarse bed load leaves the confines of fan channels during floods to spread out over wide areas of an active fan lobe (Bull, 1972; Heward, 1978a). Some massive, matrix-supported conglomerates and crudely stratified, muddy, pebbly sandstones were probably deposited by debris flows (Walker, 1975a; Miall, 1977; Rust, 1978).

Planar cross-stratification was most likely formed by migrating sand waves (Harms, 1975) and transverse (Smith, N.D., 1970, 1971, 1974), linguoid (Collinson, 1970a) or cross-channel bars (Cant, 1978). These bars are common in both sandy and gravelly braided systems. They propagate from slip faces of other bars (Rust, 1972; Smith, 1974) or are superimposed upon earlier bar deposits (Miall, 1977; Cant, 1978). The crossbeds were deposited under lower flow regime conditions (Harms, 1975) during the later stages of flood cycles.

Large-scale, trough cross-stratification was formed in channels by migrating megaripples (Collinson, 1970a; Cant, 1978; Cant and Walker, 1978). Smaller, trough crossbeds intercalated with horizontal and thinly stratified sandstones were probably deposited in shallow water as smaller megaripples migrated over the tops of large bars.

Modification of these bar tops during late, waning flood stage also produced scours that were filled by trough crossbeds.

The fine red sandstones and siltstones of facies E are associated with fine gray beds (lithofacies H) and have small scale current structures. They were, therefore, deposited in a quieter depositional setting than the coarser deposits of the facies. Small scale trough crossbedding and ripple cross-lamination was formed by migrating ripples (Harms, 1975) during the last stages of flood or at low water in the braided stream system (Miall, 1977; Cant and Walker, 1978). Fine deposits also occur in pools within abandoned or inactive channels in braided stream systems and in abandoned lobes of alluvial fans (Doeglas 1962; Williams and Rust, 1969; Heward, 1978a). Vegetation locally stabilized these deposits and desiccation cracks formed when pools dried up.

Facies E dominates megasequences and also some basin-fill sequences (Heward, 1978a) in the Mollichignick Member near the Long Range fault. These deposits are interpreted to have been laid down by alluvial fans that were built northwest of the paleo-Long Range Highlands. The apparent infrequency of debris flows (Hooke, 1967) or coarse stream gravels (Boothroyd, 1972; Boothroyd and Ashley, 1975) suggests that the observed deposits were not the most proximal deposits of the fans. Thus the mountain front may have receded east of the present day Long Range fault as a result of erosion or perhaps movement on basin-margin faults (Bull, 1972; Heward, 1978a).

The marked textural difference between the fan deposits of the Mollichignick Member and the deposits of the Overfall Brook Member may reflect a climatic change from semiarid to more humid conditions. Evidence for the change is: 1) the presence of thick caliche beds in the Mollichignick Member, but their absence in the Overfall Brook Member (Giles et al., 1966; Reeves, 1970; Steel, 1973; Allen, 1974; Leeder, 1975), and 2) the importance of clean sediment and abundant current structures in the Overfall Brook fan, indicating an active braided fluvial system typical of humid fans (McGowen and Groat, 1971; Reineck and Singh, 1975; Collinson, 1978a). It is important to note, however, that well-worked arkoses may occur in semiarid areas where streams drain a granitic terrane (Shepard, 1975).

Away from the subbasin margins, individual beds or sequences of the lithofacies are intercalated with floodplain, playa flat and lacustrine lithofacies. Here they are interpreted as deposits of sandy and gravelly braided streams. Where the facies forms the upper part of coarsening-upward sequences that include floodplain siltstones (lithofacies A) and stratified sandstones (lithofacies C), it was probably part of a prograding alluvial-fan lobe (Leeder, 1973a; Hardie et al., 1978; Heward, 1978b;). The coarsening upward may reflect increased rainfall or tectonic activity (Bull, 1972; Heward, 1978a). Both phenomena may have caused the fan-head channel to entrench so that coarse detritus bipassed the fan apex and was deposited lower on the fan or on the adjacent flood plain.

Conglomerates and pebbly sandstones in the Flat Bay section of the

Jeffrey's Village Member are associated in the lower part with playa flat shaly siltstone and in the upper part with alluvial(?) plain siltstones. The lower 200 m of the section was deposited by ephemeral braided streams carrying gravels onto the inner edge of a playa flat; calcretes then developed within, and cemented, the stream gravels. Pebble lithologies in the lower 230 m of the section suggest derivation from the Humber Arm Allochthon highlands to the north. Their absence higher in the section, and replacement by metasedimentary and silicic volcanic pebbles, indicates that the younger series of fans was built out into the basin from the northeast and east. Major scour surfaces separating beds of differing strike and dip suggest that overlap of two or more fans probably occurred. Lack of caliche and predominance of crossbeds in the upper sequence may reflect more active fluvial sedimentation (Leeder, 1975).

(F) Caliche limestone lithofacies

Description of lithofacies F: Three types of limestone occur in this lithofacies. They are (1) nodular caliche, (2) siltstone and sandstone beds cemented by carbonate and (3) thick beds of pale gray limestone. The lithofacies is present in all but the Overfall Brook Member and the Brow Pond lentil.

Caliche concretions are most common in facies A siltstones, where they vary from pea shape and size to larger, rather elongate, flat to very irregular shaped nodules. In the Highlands Member, the concretions are also associated with vertical cylindroids, (Hubert et al., 1978).

The second type of caliche consists of thoroughly or incompletely cemented beds of other lithofacies (Plate 69). As such, it includes color-mottled, pale gray to reddish gray, cemented siltstones and sandstones that form resistant rock ledges in red siltstones of the Jeffrey's Village (Figure 23, Section H) and Mollichignick Members (Figure 24, Section A and E). The calcareous siltstones typically contain small clots and nodules of almost pure carbonate, that are 0.5 to 1 cm in diameter, and they are crosscut by fractures cemented by calcite spar. Most internal structures have been destroyed. Cemented sandstone beds occur at the top of lithofacies D in the Mollichignick and Highlands Members. Lithofacies E conglomerates and pebbly sandstones are cemented in the lower 55 m of the Flat Bay section of the Jeffreys Village Member (Plate 70). Gradational, irregular and locally transgressive bases are typical of the cemented beds while tops are mostly hummocky and either sharp or gradational.

Pale, gray to purplish, microcrystalline limestone beds, 30 to 130 cm thick, form the third type of caliche, (Figure 23, see Section F, G and H; Figure 24, Section E; and Figure 25, Section A, B, C and F). The beds are internally massive, but near their tops they contain concretionary structures, 5 to 10 cm in diameter, that are associated with 0.5 to 1 cm pisolitic nodules, red siltstone partings and laminar structure (Plate 71). Stylolites may also occur. The bases and tops of the limestone beds are mostly sharp and knobby. Small caliche pipes occur in red siltstones beneath some of the thicker beds.

Although most caliches of this type are single beds, some units in the Highlands and Mollichignick Members consist of two or more beds with complex relationships between caliche and host rock. In the Highlands Member, one facies A siltstone unit (Figure 24, Section E,) contains at least three caliche horizons (Plate 72). The first occurs in a deep scour at the top of a facies D sandstone and is covered by 220 cm of red siltstone. The caliche and siltstone are crosscut by a deep channel that is filled by intraformational conglomerate (lithofacies G) and the channel-fill and siltstone are capped by 55 cm of caliche. The latter appears to be one bed above the channel, but when traced laterally outside the channel and above the siltstone, it splits into two beds, 26 cm and 20 cm thick, separated by 10 to 15 cm of siltstone. The lower 20 cm caliche bed has a sharp, but uneven contact with the interbedded siltstone. Obliquely dipping caliche dikes and cylindroids 5 to 15 cm in diameter (Plate 73) extend downward below the bed which also contains bowl-shaped deposits of calcrete (Plate 73). The latter are 45 cm in diameter and 20 cm deep, with downward-protruding pipes at the bases. The dikes and cylindroids penetrate the siltstone for up to 100 cm and many have hollow tubes, 1 to 2 cm in diameter, passing through their centres. The upper caliche bed has typical, knobby concretionary texture (Plate 72).

In the Jeffrey's Village Member at Flat Bay, some caliche units in the red shaly siltstone have a columnar structure similar to that described from Carboniferous calcretes in Kentucky (Wall et al., 1975). In the same section, a type-3 caliche limestone, 45 cm thick, lies within a conglomerate bed, 118 cm thick (Figure 23, Section H). The caliche has a sharp base but a diffuse upper contact with the conglomerate. At one place in the bed, the caliche thickens (Plate 74) and fills a depression in the underlying conglomerate. Immediately above the depression it encloses a large wedge of conglomerate that has dimensions similar to those of the depression.

Petrographically, the cemented beds consist of clots of almost pure, microcrystalline carbonate which are surrounded by very fine, mottled, cloudy, sandy and silty microspar (Plate 75). The angular detrital grains, particularly those composed of quartz and feldspar, are corroded and many are intruded by calcite veinlets; mica flakes have been dismembered by spar precipitated between cleavage planes.

The more pure caliche consists of dense, brown, cryptocrystalline micrite and silty micrite with clear microspar in streaks, patches and pore fillings (Plate 76). Discontinuous partings of fine silt, kaolinite, sericite and fibrous calcite occur within the micrite. The micrite is also characterized by irregular to wormy microfractures, angular, curved and branching dilation cracks, and fenestral-type pores filled by microspar and coarser spar.

Silicification was observed in three caliche beds along the Grand Codroy River between Limestone and Overfall Brooks (Plate 77). The chert occurs as irregular masses and stringers in microcrystalline limestone. It is red in color and either cryptocrystalline or formed of fibrous, length-fast chalcedony. The chert lies within irregular areas of slightly coarser microspar that occur within the dense, brown to light brown, microcrystalline limestones. Vugs in the chert are lined by chalcedonic colloform layering and by coarser, fibrous, length-slow chalcedony. Remaining voids were filled by calcite, equigranular quartz or hematite. Hematite occurs along the margins of the chert grains and in clots surrounding irregular nuclei of colourless chert. The carbonate has not been tinted by the hematite.

Pink, dolomitic caliche layers, 5 to 15 cm thick form bounding deposits above and below thick lithofacies D sandstone sequences at Fischells Brook (Figure 23, Section H). Similar pink caliche lies immediately beneath the lower gypsum bed at Rattling Brook (Figure 31) and may correlate with the upper pink caliche of Section H, (Figure 23).

Interpretation of lithofacies F: The carbonates of facies F resemble pedogenic caliche limestones that form in modern arid and semiarid areas (Gile et al., 1966; Reeves, 1970; Bull, 1972; Goudie, 1973; Lattman, 1973). Caliches are also well documented from ancient nonmarine strata (Steel, 1973; Allen, 1974; Leeder, 1975; Allen and Williams, 1979). They are known to develop within soils of alluvial plains, on alluvial terraces, along exposed ephemeral stream courses and on inactive areas of alluvial fans (Gile et al., 1966; Bull, 1972; Lattman, 1973; Allen, 1974). Since caliches usually take thousands of years to form and therefore only occur where sedimentation rates are low, they give some idea of these rates and of the behaviour of fluvial systems on floodplains.

The carbonates are precipitated in the 'K' horizon of soils (Gile et al., 1966). Carbonate provided to the sediment as wind-borne lime dust (Gile et al., 1966; Goudie, 1973) is leached by downward-percolating rainwater and is precipitated in the subsurface when the soil waters evaporate during the dry season. Thickening of the 'K' horizon continues as carbonate is precipitated, with repeated wetting and drying of the sediment for hundreds or thousands of years. Consequently, caliche profiles change with time as carbonate buildup progresses (Table 1 of Gile et al., 1966; Leeder, 1975). Long-lived caliche formation occurs when permeability, allowing downward percolation of mineralized rain water, is maintained. Where permeability is reduced, the mature profile will be plugged by carbonate so that a laminar layer develops above the nodular caliche. Laminar layers generally indicate old deposits, but both Reeves (1970) and Lattman (1973) showed that the structure can also develop in younger deposits where original permeability is poor. The presence of "cylindroids" some with hollow tubular centres, in the thick caliche of the Highlands Members, suggests that in some instances, the caliche was precipitated on biogenic soils around extensive root systems (Hubert, 1977).

Four stages of caliche that include the three caliche types recorded in facies H are defined by Gile et al., 1966. Filaments and coated grains typical of Stage I were not found in the Robinsons River Formation, but nodular caliche similar to stage II (Gile et al., 1966) of young profiles (Reeves, 1970) is common; this requires 3000 to 7000 years to form (Leeder, 1975). Continuous beds and lumps of carbonate-cemented siltstones, sandstones and conglomerates with embryonic pure calcite nodules represent stage III (Gile et al., 1966), which is typical of early and later mature profiles (Reeves, 1970). This stage probably lasted 6000 to 10,000 years (Leeder, 1975). Thick nodular, massive, brecciated, laminar, locally pisolitic and cherty pure limestones represent stage IV (Gile et al., 1966). They are indicative of old caliche profiles (Reeves, 1970) which require more than 10,000 years to form (Leeder, 1975). Etching, dissolution and replacement of detrital sand grains by calcite is common and progresses with profile maturity (Steel, 1973).

Young profiles of small nodular caliche are common in floodplain siltstones, and levee and crevasse splay deposits of all three host members. In the Jeffrey's Village Member, old profiles are not common but do occur in the Flat Bay section where they formed in both playa flat and gravelly braided stream deposits. A few mature and old caliches and dolomitic caliche beds also occur in the Fischells Brook section just above the Heatherton limestone. Here they are closely associated with floodplain and sandy braided stream deposits. This suggests that fluvial sedimentation of the redbeds immediately above the Fischells limestone was intermittent with long periods of nondeposition. Lack of all but small nodular caliche in the fine redbeds of the upper part of the Jeffrey's Village Member suggests increase in sedimentation rate with time (Leeder, 1975). Dolomitic caliche associated with both fluviatile deposits and marine beds may indicate that some caliches were affected by marine flooding or salt spray from a nearby marine shoreline (Scholle and Kinsman, 1974).

Young to mature caliche profiles in the Highlands Member are common, but old profiles are found only in the middle of the member. The scarcity of old profiles may in part reflect high sedimentation rates, but the abundance of caliche intraclasts in channel deposits also suggests extensive reworking of floodplain deposits by rivers.

Caliche limestones occur in both axial floodplain and marginal alluvial fan sequences in the Mollichignick Member. However, the floodplain sequences generally correspond to caliche-rich sections and the alluvial fan sequences to caliche-free sections. This distribution is apparently maintained when the succession is traced laterally toward the margins of the subbasin, which suggests a long-term allocyclical control such as tectonic activity or climatic variation (Allen, 1974; Leeder, 1975). Caliche-free successions correspond to prolonged periods of high sedimentation, and the progradation of sandy and pebbly alluvial fans into the basin. Autocyclical controls, for instance the morphology of the alluvial plain, channel switching and river entrenchment (Allen, 1974; Allen and Williams, 1979), influenced the local caliche distribution within the caliche-rich sections. In these sections, carbonate cementation of the top beds of channel sandstones (Figure 25, Section B) may indicate rapid abandonment of river channels followed by extended depositional hiatuses. Old and siliceous caliches suggest major breaks in sedimentation lasting 10,000 years or more (Leeder, 1975). The presence of more than one caliche bed in a sequence may have resulted from the elevation of some areas of the floodplain (Allen, 1974), which then remained as zones of non-deposition except during major floods.

Lack of caliche in the Overfall Brook Member may reflect increased humidity so that higher sedimentation rates (Leeder, 1975) and increased mineral leaching (Reeves, 1970) prevented soil development and precipitation of carbonate.

(G) Intraformational conglomerate lithofacies

Description of lithofacies G: Intraformational conglomerates composed of caliche pebbles and mudclasts form discrete, channel-bound deposits within lithofacies A siltstones. The deposits are 14 to 387 cm thick in the Highlands Member but rarely thicker than 70 cm in the Mollichignick Member. They are brown, red and white in color and their bases are erosive into the host siltstones. Two types occur: the first lacks extrabasinal sand or pebbles, and the second is mixed with quartz sand and some white quartz pebbles. Channelling is present in both types (Figure 24, Sections E and F). One channel in the Highlands Member (Figure 24, Section E) was eroded into a 220 cm red siltstone unit and was later capped by caliche (Plate 72). The channel, 282 cm deep, is scoured irregularly and steeply through the siltstone and has eroded deeper where the siltstone fills an abandoned chute channel in the top of the underlying, fining-upward channel sandstone. Caliche pebbles, which are 1 to 2 cm in size, show little modification of their nodular shape and are set in a matrix of sand-size caliche fragments and mud chips. Crude stratification and crossbedding with lenticular sandy layers characterize the channel deposits, and large scale trough crossbedding, 50 cm thick, occurs throughout the thickest deposit of this facies in the Highlands Member (Figure 24, Section F).

Interpretation of lithofacies G: The thick, channel-bound deposits form a minor lithofacies that resulted from peculiar processes on the flood plain. The predominance of caliche and mud clasts in the conglomerates and the rarity of extrabasinal detritus suggests that the depositing fluvial system originated within the basin, reworking floodplain alluvium and its contained pedogenic horizons. Where this fluvial system tapped an older channel sand, quartz sand and pebbles were also mixed into the deposits. Deep channelling suggests high energy events with the ability to erode and transport caliche pebbles. Little modification of original nodule shape by abrasion indicates generally short-lived events. The large crossbeds, 50 cm thick, probably formed in large megaripples (Williams, 1971; Karcz, 1972; Allen and Williams, 1979).

The evidence indicates that the lithofacies formed in response to high energy, short-lived floods which eroded channels in the floodplain sediments. They were generated on the flood plain and were independent of rivers entering the subbasin from outside its perimeter. Such deposits are capped by siltstone and caliche limestones because they formed locally and were rarely repeated in the same geographic locality. Catastrophic local superfloods which scour and flush out all available sediment are documented for small drainage basins of arid regions of the southwestern United States and semiarid areas of central Texas (Baker, 1977).

Similar deposits were recently described by Allen and Williams (1979) in the Siluro-Devonian redbeds of South Wales where the conglomerates overlie thick caliche limestones. They interpreted the deposits as products of ephemeral, braided streams, generated on elevated interfluvial geomorphic surfaces between large, perennial meandering river systems.

(H) Gray, carbonaceous and micaceous mudstone-siltstone lithofacies

Description of lithofacies H: Lithofacies H occurs in the Mollichignick and Overfall Brook Members. In the Mollichignick Member, the facies is between 0.5 and 6 m thick and consists of thin and flat bedded, intercalated dark to light gray mudstones and siltstones, containing lenses and beds of gray arkosic sandstone. The bedded mudstones and siltstones are locally deformed by sedimentary faults, slump folds and brecciation. The lenticular sandstones occur toward the top of the bedded lutites, and have eroded into them, enclosing fragments as large intraclasts. The lenticular deposits are then capped by trough crossbedded, gritty and pebbly gray arkosic sandstones (lithofacies E) to form overall coarsening-upward sequences, 1 to 8.6 m thick (Figure 21; Figure 26, lower lacustrine sequence section B).

In the Overfall Brook Member, the facies is slighty different occurring in poorly exposed, recessive units 0.5 to 4 m thick. The units consist of beds, 10-25 cm thick, of gray silty mudstones and muddy siltstones, very fine to fine grained sandstones that are gray to pinkish gray, and minor shales. Apart from their color, the sediments of this facies are characterized by micas and carbonaceous plant fragments. Typical sedimentary structures in the sandstones are basal scours, crossbedding, lamination and cross-lamination, convolution of ripple-drift, and small pockets of grit; plant rootlets have disrupted the laminations and ripple-drift. The shales, which may occur as thin lenses or partings between or in the sandstone beds, have mudcracks, whilst the mudstones are mostly structureless.

Interpretation of lithofacies H: The gray color, abundant plant debris, high mica content and fine grain size contrast with the oxidized and coarser deposits with which the facies is mostly associated. In the Mollichignick Member, the flat, thinly interbedded gray mudstones and siltstones were probably deposited in a quiet, shallow lacustrine setting. The association of the lutites with gray sandstones in coarsening-upward sequences suggests the lake bottom sediments were buried by sandy deltas prograding over the quiet lake muds.

Small lakes were also the probable depositional environment of the facies within the Overfall Brook Member. Current structures typical of low energy flow conditions (Harms, 1975), abundance of micas, plant trash and shale interbeds suggest quiet restricted conditions in which fines were readily trapped to the exclusion of the coarse debris. The lakes may have formed in abandoned braid channels upon the alluvial fan (cf. Meckel, 1975).

(I) Intercalated calcareous mudstone - carbonate - micaceous sandstone lithofacies

Description of lithofacies I: This facies occurs exclusively in the Mollichignick Member where it forms sequences up to 50 m thick in the lower half of the member (Figure 26, Section A, upper lacustrine sequence Section B, and Section C). The facies consists of three rock types: drab gray, calcareous mudstones; nodular, concretionary and bedded dark gray to black carbonates; and gray, very fine to fine grained, micaceous sandstones (Plates 78 to 81).

The three lithologies are arranged in two different associations. In the thickest unit (Figure 26, Section A) the first association begins and finishes with micaceous sandstones that sandwich a thick middle development of mudstone and carbonate with some thin sandstone beds. In the second association (Figure 26, Section B, and probably partly by Section C) the rocks form coarsening-upward sequences, 2 to 6 m thick, beginning with intercalated mudstone and carbonate and completed by sandstone.

The drab, gray calcareous mudstones consist mostly of massive beds, 10 to 60 cm thick, with some thin layers that are laminated or fissile. The mudstones which are interbedded with carbonate beds, 5 to 10 cm thick (Plate 78) are petroliferous, carbonaceous, and locally contain ostracod fragments and small dolomite nodules. Large burrows are common in some beds, whilst in others there are fine tubular burrows, that are preserved by calcite spar and are about 1 mm in diameter. Some beds are brecciated and the fractures filled by mudstone: irregular spar-filled fractures cut through both carbonate and mudstone.

The carbonates consist of black to dark gray, bituminous limestones and bedded and concretionary dolomitic limestones and dolomites. The bedded carbonates, which are cryptocrystalline and contain ostracods, are structureless except for some fine bioturbation and poorly developed lamination. The concretionary dolomites are composed of small nodules (Plate 79) and angular, platy, brecciated dolomite fragments, set in a carbonate or mudstone matrix. The nodules are structureless but the fragments show a faint lamination and very fine spidery network of tubules. Narrow spar-filled dilation fractures occur around nodules (Plate 80). The fractures curve around the particles and short splays branch off them at intervals.

Dark to light gray, micaceous, very fine to medium grained sandstones, rich in plant remains, occur in sequences 1 to 5 m thick. Sandstone beds, 5 to 45 cm thick, are interbedded with gray shale beds 10 to 30 cm thick. Erosional bases and planar and undulose lamination (Plate 81) characterize the sandstones. They also have some small, shallow crossbeds, ripple cross-lamination, symmetrical convolution, and large burrows. The flat stratification in the deposits of section C, Figure 26, is defined by grain size and sorting of micas from quartz and feldspar. Laminations are inversely graded when the sandstones themselves coarsen upward but normally graded when the sandstones fine upward. Trough crossbedded, intraclastic, fine to medium grained sandstones up to 2 m thick lie with erosive bases upon the finer micaceous sandstones or mudstones of the facies. The cross-beds, which are locally convoluted, are 5 to 15 cm thick and up to 1 m in length.

Interpretation of lithofacies I: The sediments of lithofacies I were deposited in quiet, perennial lakes and are interpreted as lake-centre muds and carbonates, paludal muds and carbonates, and marginal sands.

General lack of dessication features in the fine lacustrine deposits suggests the lakes were long-lived features. Fine tubular burrows may indicate that worm colonies flourished in the lakes (Reineck and Singh, 1975). Larger burrows were possibly produced by roots of aquatic plants which may have been abundant since both mudstones and limestones are petroliferous.

Some of the calcareous mudstones contain concretionary carbonate, and brecciation textures typical of paludal carbonates. They indicate that postdepositional, pedogenic and subaerial diagenetic processes affected the exposed lacustrine deposits (Freytot, 1973). Fine mottling in the laminated breccia fragments may represent calcified rootlets (Klappa, 1979), and lamination and abundant spar-filled fractures resemble the laminar structure and dilation cracks of caliche (Steel, 1973). The curved branching fractures are like structures described by Freytot (1973) from pedogenically altered lake and marsh mudstones and limestones. This suggests the nodules may have grown in zones of water-table oscillation where carbonate was concentrated. Fractures formed as the sediments were repeatedly moistened and dried out.

Algal mats, with fine lamination rich in fenestral porosity, flourished in sheltered shoreline settings around the lake or in shallow pools in the marsh environment.

Fine micaceous sandy detritus was supplied to the margins of the lakes by shallow streams and rivers. The sandstones were laid down as broad sheets during floods and are overlain by shales that were deposited from suspension between flood events. Many coarsening-upward sequences were formed as deltas built out into the lake. Coarser grained, crossbedded sandstones probably represent channel deposits. Planar, thinly stratified sandstones, again in coarsening-upward sequences, but with grain size and mineral sorting, may be beach deposits. Alternatively they may have been deposited by ephemeral streams that were generated during flash floods (Frostick and Reid, 1977) and prograded into the margin of the lake. The disturbance of the delta and beach sands by plant rootlets suggests that vegetation flourished around the edges of the lake.

(J) Pebbly mudstone lithofacies

Description of lithofacies J: This facies is rare and has only been noted in the Overfall Brook Member (Figure 22) and the Jeffreys Village Member at Flat Bay (Figure 23, Section H). In the Overfall Brook Member it occurs with gray beds of lithofacies H or lies upon red siltstones. In the Jeffreys Village Member, it is associated with interbedded green-gray sandstones and siltstones within dominantly red, shaly siltstones of lithofacies K.

The facies is composed of poorly sorted, gray mudstone with silt, sand and grit particles, and muddy, gritty sandstone; bed thickness is 30 to 70 cm. The beds have sharp, undulose bsaes with no evidence of erosion or incorporation of underlying beds. The mudstones are internally structureless and ungraded. The granules are mostly 2 to 4 mm, angular, unoriented, quartz and feldspar grains, but some 1 cm pebbles also occur. The pebbly mudstones contain carbonized plant remains.

Interpretation of lithofacies J: Poorly sorted structureless diamictites with nonerosive bases that make up this facies are probably mudflow deposits. The lateral extent of the deposits is not known but the facies associations and thin development suggest both that the lateral extent is small and that the flows are of local origin. They probably formed by the failure and mixing of deposits of gravel, sand and mud that had soaked up floodwater or rainwater. In the Overfall Brook Member, slumping produced a mud slurry which flowed into adjacent depressions such as small lakes and abandoned, partly filled stream channels. In the Flat Bay section, the diamictites were laid down on playa flats. This suggests that they were formed by mobilisation of deposits at the foot of a nearby alluvial fans.

(K) Red shaly siltstone lithofacies

Description of lithofacies K: Important sequences of this lithofacies are found in the Jeffrey's Village Member at Flat Bay and in the Mollichignick Member. In both members, the facies is associated with both marine and nonmarine lithofacies (Figure 23, Section H and Figure 28, Sections A and B). Sequences vary from < 1 m to 115 m thick.

The lithofacies is composed of red or gray, calcareous, shaly siltstones, red coarse siltstones and very fine sandstones, and carbonates (Plate 82). Red shaly siltstones predominate. They possess a poor to good fissility, and fine, flat to undulose lamination. Rare massive beds interrupt the shaly deposits, particularly in the Mollichignick Member. Interbedded in the shaly siltstones at 3 to 10 cm intervals are beds of calcareous, coarse siltstone and very fine sandstone. These beds are rarely greater than 10 cm thick in the Jeffrey's Village Member, but are up to 25 cm thick in the Mollichignick Member. They lie both gradationally and sharply within the shaly siltstones and are locally erosive. Bedding in the siltstones and sandstones is wavy and lenticular. The main sedimentary structures are cross-lamination, wavy lamination and, in the thickest beds, crossbedding that infills broad shallow scours. Mudcracks occur in the redbeds of both members.

The carbonates consist of nodular layers and beds 1 to 4 cm thick. They are red and gray in color and are composed of microspar and detrital silt grains. Lithological contacts may be diffuse and irregular, but more commonly bases are sharp and flat and tops are somewhat rough. Many beds show no structure whilst others clearly are grain size graded, with wavy, coarse, indistinct lamination passing up into finer lamination. Green reduction spots, vugs, and fine, randomly oriented fractures are common. The vugs are lensoid, spherical or bird's-eye shaped and are filled with coarse white spar; the fractures are also filled with spar. Many thin carbonate beds at Flat Bay also contain systems of 1 mm, spar-filled tubules which branch across and through the beds. Small clusters of millimetre-size, rhomboid pseudomorphs after gypsum occur in one carbonate bed just above the marine limestones low in the Flat Bay section (Figure 31).

In the Mollichignick Member, beds and laminae of dolomitic limestone and dolomite are interlayered with drab gray siltstones in the redbed units. The 10 to 38 cm thick dolomite beds consist of fine lamination and thin stratification. Laminations are disrupted by dessication cracks with polygon edges curled up. In some beds, the laminated dolomites were reworked to form local intraformational breccias.

Interpretation of lithofacies K: This facies contains the characteristics of a highly oxidized, low-lying, playa flat. From the associated lithofacies, this facies appears to have been deposited adjacent to a shallow marine or lacustrine shoreline and to have been flanked on the landward side by alluvial fans. The fine lamination of the siltstones and the thin sheets of coarser detritus, including graded silty carbonate beds that display lamination, suggest that sediment was transported and deposited by shallow sheetfloods. The fine detritus was probably derived from adjacent alluvial fans and by reworking of syndepositional carbonate units (cf. Eugster and Hardie, 1975). Minor channels represented by the somewhat thicker cross-bedded sandstones locally crossed the mudflats.

The playa flats were calcareous. This is particularly true of the Flat Bay section of the Jeffrey's Village Member where carbonate beds are more common than in the Mollichignick Member. Many of these beds may have been precipitated during dry seasons from groundwaters saturated with calcium bicarbonate. Some of the carbonates resemble caliche limestones whilst others were probably soft carbonate muds (cf. Eugster and Hardie, 1975) that were easily reworked to form graded, laminated beds. The general absence of sulphate minerals in the facies suggests that evaporitic conditions rarely prevailed in the mudflats of the Jeffrey's Village Member; exceptions are in beds that lie near marine units, as do those at Flat Bay. Laminated dolomitic limestones and dolomites in the Mollichignick Member were formed by algal mats that grew in shallow pools when the mudflats were flooded with seawater. When the pools dried up the mats were dessicated and produced mudchip breccias.

(L) Bedded mudstone-siltstone/sandstone-carbonate lithofacies

Description of lithofacies L: Gray siliciclastics associated with carbonates occur in units up to 6.5 m thick in the Mollichignick Member (Plate 83; Figure 27). In this member, the lithofacies includes dull gray, calcareous mudstone and shale, gray, micaceous, coarse siltstone or very fine sandstone, and yellow weathering, calcic dolomite and dolomitic limestone. In the Highlands Member there are two units, 90 and 300 cm thick, in which red-mottled, green mudstone is overlain by ripple cross-laminated and planar-laminated, white, quartzose sandstone; the sandstone is capped by gray, wavy bedded, fossiliferous limestone (Figure 24, Sections A and B). The facies is also developed for a few metres above JVL-2 limestone on Fischells Brook (Figure 28) and above the Crabbes limestone at Crabbes Head (Figure 31). In both instances, the facies consists of coarsening-upward sequences of red or red and green mottled mudstones and siltstones, and ripple cross-laminated and laminated red and gray fossiliferous quartzose sandstones. The coarsening-upward sequences are capped by thin fossiliferous limestones and calcretes. Buff weathering, fossiliferous, massive bedded quartzose sandstones overlying dolomitic, fossiliferous packstones and capped by calcrete occur in the Jeffrey's Village Member along the North Branch River near the "round valley", Codroy lowlands.

The siliciclastic rocks in the Mollichignick Member are micaceous. They consist of lenticular beds of coarse siltstone or very fine sandstone, which are up to 30 cm thick (Plate 84) and are separated by 3 to 10 cm of black shale or mudstone with siltstone laminae. Many of the siltstone beds overlie the mudstone gradationally. The coarser beds have mostly planar to undulose thin stratification in which there is compositional and grain size grading. Scour and fill structures also occur, together with small crossbeds, cross-lamination, convolute bedding and wavy and flaser bedding (Reineck and Wunderlich, 1968). The cross-lamination is associated with rib-and-furrow structures and straight to sinuous ripple-marks, and there are both shale and coal flasers. Compositional and grain size grading occurs in the thin stratification. Trough-shaped scour and fill structures, up to 150 cm wide and trending northwest-southeast, are filled symmetrically by thin stratification.

Yellow weathering calcic dolomite, dolomitic limestone and gray limestone form lenses and beds, 10 to 60 cm thick, within the gray siliciclastic rocks of the Mollichignick Member (Plate 83). The carbonates vary from lime mudstones to argillaceous, skeletal wackestones and packstones (Dunham, 1962). Internally, they are thinly stratified, laminated or structureless (Plate 85). Tepee structures (Asserretto and Kendall, 1977), dessication cracks and local mudchip breccias occur at the tops of laminated beds. Single or locally clustered nodules of blocky calcite spar occur with pink gypsum crystals in some of the carbonate beds (Plates 83 and 85). They resemble the calcitized nodules, after anhydrite, described by Lucia (1972). Fenestral and intraparticle porosity (Choquette and Pray, 1970), and tubular burrows, 0.1 to 0.5 mm in diameter, also occur.

Skeletal components include whole and fragmented ostracods, small plani spiral and high spiral gastropods, bivalve shell fragments, crinoid ossicles, the sedentary foraminifera **Tubertina** (Mamet, 1970) and vertebrate fragments. The skeletal grains are mixed with indistinct micritic peloids and both allochems are set in a dark brown, lime mud matrix that locally contains dark carbonaceous films of probable algal origin and scattered 0.02 mm dolomite rhombs.

Dissolution of mollusc and ostracod shells produced moldic porosity in skeletal layers, which is filled by blocky spar. Shell chambers are lined with fine, acicular druses and the remaining open spaces are closed by blocky spar. Partial collapse of some shells predated precipitation of the blocky spar.

In the Highlands Member, the carbonates are clean, sandy grainstones and peloid-rich packstones. The beds are structureless to wavy bedded with local brecciation. Mudcracks, tepee structures and brecciation affect thin planar stratification at the tops of the limestones. The grainstones include siliciclastic grains mixed with abundant whole and fragmented skeletal grains, oncolites and intraclasts. Skeletal fragments include high-spiral gastropods, ostracods, calcispheres, colonial Dasycladacean algal cysts (Marszalek, 1975) and numerous foraminifera similar to Pseudoglomospira sp? (cf. Mamet, 1970). Cloudy micritic peloids and coated carbonate grains are also common. Acicular cements line ostracod shells but most porosity within or interstitial to grains is filled by clear calcite spar. Micritisation of grains was common and the edges of some unicrystalline (crinoid ?) calcite grains have been partly replaced by micrite. The mollusc Aviculopecten, and in the "round valley", Codroy lowlands, the bryozoan Streblopteria biformata (Bell, 1929; Moore and Ryan, 1976) occur in the siliciclastics and carbonates of the Jeffrey's Village Member.

Interpretation of lithofacies L: In the Mollichignick Member, the siliciclastic rocks have a high mica content and the mudstones are intercalated with siltstones and sandstones, so that there is a resemblance to the lacustrine deposits of lithofacies I. The presence of carbonates containing a marine fauna, however, indicates deposition in a marine or brackish marine environment. Flaser, wavy and lenticular bedding in the siliciclastics also indicates shallow marine, near-shore sedimentation (Reineck and Wunderlich, 1968). The environment was probably a shallow bay or lagoon, into which micaceous, muddy detritus was carried by shallow streams and rivers. Evidence of the latter is provided by the thick unit of crossbedded sandstones (lithofacies O) which overlies the marine deposits (Figure 27, section B).

At times when there was little detritus reaching the bay or lagoon, it became the site of carbonate deposition and hosted a shelly fauna dominated by ostracods and gastropods. The crinoid ossicles suggest that at times the marine waters had near normal salinity (Horowitz and Potter, 1971; Heckel, 1972). The dominant shelly faunas, however, could also have thrived under brackish or hypersaline conditions (Heckel, 1972).

Carbonaceous laminae suggest that algal mats helped bind sediment in the shallow lagoons, and carbonates accumulated on the algal flats as the lagoonal muds became emergent with regression. Small tepee structures (Asserretto and Kendall, 1977), calcitized anhydrite nodules and partially dolomitized limestones suggest that the algal flats were subject to penecontemporaneous, diagenetic processes typical of modern sabkhas (Shearman, 1966; Kendall and Skipwith, 1968; Kinsman, 1969).

The acicular microspar druse in intraparticle and shelter porosity suggests early cementation that was either shallow subtidal or else marine vadose in the intertidal zone (Taylor and Illing, 1969; Shinn, 1969). Dissolution of shelly material and nodular anhydrite in the carbonates, and precipitation of clear blocky spar in the resulting porosity, probably records later fresh water diagenesis and cementation with the onset of non marine conditions.

The coarsening-upward sequences in the Jeffrey's Village and Highlands Members are interpreted as the product of a shallow prograding shoreline. Deposition of shallow lagoonal muds was followed by accumulation of well sorted, ripple-bedded, shoreline or sandbar siltstones and sandstones. These were superceded by deposition of low energy, lagoonal pel-packstones and in the Highlands Member also by higher energy, fossil-bearing sandy grainstones. The fauna of calcispheres, ostracods, gastropods and abundant <u>Pseudoglomospira</u> indicate relatively high salinities (Mamet, 1970; Marszalek, 1975). Tepee structures and brecciation of the thin stratification at the tops of the limestones suggest algal flats that were subject to vadose diagenesis as the carbonates became emergent (Asserretto and Kendall, 1977).

(M) Gray shale/mudstone - siltstone/sandstone lithofacies

Description of lithofacies M: Lithofacies M is composed of shales or mudstones that are interbedded with lenticular and bedded, coarse grained siltstones and fine grained sandstones. The shales and mudstones are gray, gray-green or black, and the siltstones and sandstones are gray but weather buff. The facies occurs in units 1 to 8 m thick and is well developed in both the Jeffrey's Village (Plate 86; Figure 28) and Mollichignick Members (Plate 87; Figure 27, Sections A and B).

Two associations occur: the first, in both members, consists of shales and sandstones in coarsening-upward sequences, and the second, which occurs only in the Jeffrey's Village Member (Figure 28), consists of siltstones and mudstones intercalated with sandstones.

In the first association, repetitive coarsening-upward sequences, each up to 100 cm thick, are composed of shales or mudstones and sandstones. Shales near the base of the sequences give way upward into lenticular or evenly bedded (2 to 3 cm) sandstones below one or more 10-25 cm thick beds of sandstone. In both the Stinking Cove and Crabbes Head sections, the younger sequence is capped by 120 cm thick sandstone beds (Figure 28).

The black and gray generally fissile shales commonly contain oncoliths and fossil-bearing, carbonate concretions, 1 to 2 cm in diameter; scattered fossils are also present. The fossils in the Jeffrey's Village Member include gastropods, probably **Spirorbis**, the bivalve **Lithophagus poolii**, the branchiopod **Leaia**, the coral **Paraconularia** and the bryozoan(?) Palaeocrisidia (Nodosinella) (Bell, 1948, Fong, pers comm., 1976; Moore and Ryan, 1976). Bivalves identified as **Edmondia hartii** and **Aviculopecten cf lyelli**, (McGlynn, personal communication, 1978), compacted unidentifiable brachiopods, inarticulate brachiopods, gastropods, some ostracods, a few pentagonal crinoid ossicles and a straight cephalopod were noted in shales of the Mollichignick Member. The shales are bioturbated, but this is not readily seen except where convex hyporelief (Basan, 1978) has preserved trails and burrows at the bases of sandstone beds. Bioturbation, probably by bivalves, completely disrupted and mixed some beds in the Mollichignick Member on Mollichignick Brook.

Sandstones are generally well sorted, very fine to fine grained, and rich in mica, fine plant debris and gray, discoid shale clasts. In the middle of the sequences, wavy bedded and lenticular sandstones have sharp erosional bases and flat or rippled tops. The sandstones at the tops of the coarsening-upward sequences also lie erosively upon the underlying strata, although in some sequences there is a gradation from shale to sandstone and the scour is developed midway through the sandstone. Internally, the sandstones have flat, undulose and gently inclined laminations, some of which carry parting lineations. There is also ripple cross-lamination, flaser bedding, and some small scale trough and planar crossbedding. Convolute bedding causes hummocky tops in some of the beds, and there are many small scale, straight to sinuous ripple-marks which bifurcate and locally interfere with one another. In the Jeffrey's Village Member, bedding planes are roughened by bioturbation which includes burrows that are meandering and tubular or funnel- and plug-shaped (Frey and Howard, 1970;

Chamberlain, 1978). U-shaped burrows (Plate 88) similar to **Arenicolites** and **Diplocraterion** (Frey and Howard, 1970; Chamberlain, 1978) and fine **Chondrites** patterns are common in the Mollichignick Member, as are randomly oriented tubular burrows.

Halite pseudomorphs, spherical molds after anhydrite (?) and some thin gypsum beds, 1 to 2 cm thick (Figure 28, Highlands Section) are locally associated with the facies.

The second association occurs in the 17 m immediately beneath the Fischells limestone (Figure 28) and consists of three fining-upward sequences 4 to 6.5 m thick. These are formed of green-gray sandstones and siltstones, and gray mudstones. Some of the sandstones are dolomitic and weather buff-yellow, and others are flaser bedded. Ripple-marked, calcareous, silty, fine sandstones occur toward the top of the upper sequence. Siltstones interbedded with the mudstones are graded.

The bases of the sequences are each marked by an irregular scour. Well sorted, very fine sandstones and coarse siltstones, 60 cm to 2 m thick, occur above the scours. They display planar thin stratification and lamination, with good to indistinct parting lineations. They also have ripple-drift cross-lamination or small, trough crossbeds, 5 to 10 cm thick and 50 cm long. Mudclast lags, some with good imbrication giving flow direction to the southwest and northwest, lie along the basal scours. Large planar crossbeds, 60 to 100 cm thick, form the tops of the sandstones and are capped by planar lamination of the upper flow regime, or by ripple cross-lamination. Shale flasers and partings occur in the upper parts of the sandstone beds.

A channel is eroded into dolomitic sandstone at the base of the second fining-upward sequence of this section. It is filled by several 15 cm beds of planar-laminated sandstone (Plate 89) that thicken into the channels but thin as they drape over the channel edges. The sandstone beds are separated by mudcracked mudstone drapes, 1 to 3 cm thick which have been reworked locally to form intraclasts in the sandstone as it is traced laterally into the channel.

In each sequence, the planar laminated sandstones are overlain by beds of silty, very fine sandstone up to 42 cm thick. These show flaser bedding, ripple cross-lamination, and flat lamination, and contain lenses and beds of mudstone. The flaser-bedded sandstones are, in turn, overlain by graded beds of siltstone and mudstone, 35 to 215 cm thick. The siltstones have sharp, flat to irregular scour bases and are laminated and ripple cross-laminated. Shale flasers occur increasingly toward the top of siltstones and thin siltstone layers, and lenses occur in the overlying mudstones. The mudstones are structureless except for some silt streaks and dolomite laminae. Fine burrow mottling occurs locally at the tops of the mudstones in the second and third fining-upward sequences.

Ripple-marked, calcareous, silty, very fine sandstones are interbedded with the mudstones in the upper sequence to form some coarsening-upward couplets. Internally, they appear massive but also have fine wavy lamination, festoon ripple cross-lamination, shale flasers, and some irregular burrows. Straight, symmetrical ripple marks, interference ripple marks and rain pits occur on the tops of beds.

Current directions in the second association are to the northeast or east, except where has been otherwise noted.

Interpretation of lithofacies M: The first association of lithofacies M contains a record of repetitive low and high energy deposition in a restricted marine setting. Quiet water shales suggest a protected environment such as a back barrier lagoon (Hayes and Kana, 1976; Reinson, 1979). Carbonate concretions and beds, halite and gypsum pseudomorphs, gypsum beds and the low density, small infauna show that salinities varied considerably (Elliott, 1978b). The branchiopod, **Leaia** (Bell, 1948), may be a brackish-water form (Heckel, 1972), but other species and the abundant bioturbation are consistent with near-normal marine conditions for much of the time. The ichnofossils are generally similar to those expected in near-shore or lagoonal environments (Howard, 1972; Chamberlain, 1978).

Interrupting the dominantly quiet sedimentation were episodes of deposition of fine sand and coarse silt. Gradational bases in some thicker sandstones and the gradual coarsening upward due to the increase of thin sand lenses and beds in the shales suggest progradation of sands over the lagoonal muds. Erosion at the base of or within sandstones indicates that high-energy, storm events periodically affected the lagoons. Sand deposits filling modern back-barrier lagoons include washover fans, tidal sand flats and deltas, aeolian dunes, small deltas and prograding beach deposits (Klein, 1975; Hayes and Kana, 1976; Barwis, 1976; Elliott, 1978b). Small-scale sedimentary structures support intertidal flat to beach environments for these sand deposits. The most diagnostic of these structures are ripple marks, ripple cross-lamination, flaser bedding and low-angle, undulose to flat lamination. Lagoons form behind physical barriers, which in this case were either algal banks (Figure 28), or sand spits and barrier sands, since the overall succession is dominated by terrigenous nonmarine sediments.

The thickness of the shale-sandstone couplets and of sand bodies in this facies suggests tidal ranges were probably less than 100 cm and hence microtidal (Hayes and Kana, 1976; Davis, 1978). The repetitive deposition of shale and sandstone couplets over several metres implies that although shallow, the lagoon was maintained by steady subsidence.

The second association, located below the Fischells limestone, was also deposited in a shallow marine nearshore setting. A marine aspect is supported by the stratigraphic position of the section below the Fischells limestone. In addition, flaser and lenticular bedding, bioturbation, symmetrical and interference ripple marks and bimodal paleocurrents suggest the sediments were laid down in the intertidal zone. Unlike the sequences of the first association, however, those of the second fine upwards and consist of scour-based, crossbedded and planar-stratified sandstones that are overlain by flaser bedded fine sediments. These fining-upwards sequences resemble closely those described in prograding tidal flats (Reineck, 1975; Elliott, 1978b). The current bedded sands which also have a basal mudchip lag deposit and locally display channelling were likely deposited in the lower part of the tidal flat associated with migrating tidal channels. Overlying these sands, flaser bedded fine sediments were laid down on mudflats higher in the intertidal zone. Ripple-marked, flaser bedded, rain-pitted and bioturbated, calcareous siltstones overlying mudstones at the top of the section, just below the Fischells limestones, were, like association A, perhaps deposited in a shallow prograding shoreline. Alternatively, they represent deposits that formed still higher on the tidal flat perhaps similar to the inner sand flats described by Evans (1965, 1975) in the Wash, eastern England.

The basal sequence of the section overlies fluvial-deltaic red and green siltstones and sandstones implying that the marine environment transgressed over and probably reworked abandoned delta deposits.

(N) Varicolored mudstone lithofacies

Description of lithofacies N: The varicolored mudstone facies is found only in the lower part of the Jeffreys Village Member and is well exposed along Fischells Brook below the Fischells limestone (Figure 29, Sections A, C and D). It also occurs in tightly folded and faulted strata at Ship Cove, north of the Cormorant limestone. The facies units along Fischells Brook vary from 10 to 500 cm in thickness and there are at least eighteen units exposed. The facies is characterized by red, green-gray, blue-gray and black colored mudstones which may be slightly calcareous.

Two variations of the facies occur. The first consists of mudstones with color bands that alternate on a scale of 1 mm to 5 cm, and the second of dark-colored mudstones in 160 cm units. In the rapidly alternating variety, the color changes coincide with slight variations in grain size and texture. Red layers are mostly massive mudstone whilst green-gray and blue-gray bands consist of coarse siltstone and mudstone with flat to microconvoluted, commonly discontinuous laminae. Black mudstones are thinly stratified with structureless and laminated layers. Red color bands are generally concentrated toward the tops and bottoms of the deposits with rapidly alternating color bands, although a few red bands also occupy the centres of these units.

Apart from the fine lamination and microconvolution, which is symmetrical and gives a fluffy bulbous appearance to laminae, sedimentary structures are rare in the varicolored laminite. Mudcracks were observed in only three units in the Fischells Brook section and were not encountered at the Ship Cove section. Cubic and some rhombic crystal molds are concentrated in thin beds or along specific laminae in the red mudstones, and less commonly the other color bands; they are pinpoint to 7 mm in size. The crystals molds are lined or filled by yellow weathering siderite.

A number of units consist completely of black mudstone (Figure 29, Section B). These mudstones are thinly stratified and have been affected by slump folds and sedimentary thrusts which distort major portions of the units.

Sequences of gray, very fine grained sandstone and black shale (Plate 90) occur in the laminated variety of the facies on Fischells Brook (Figure 29, Section A). They are located at the bases and tops of two of the oldest units and are between 22 and 36 cm thick. The sequences consist of ripple-marked or wavy bedded sand sheets, 2 to 4 cm thick, separated by mudcracked black shale; the sandstones contain halite pseudomorphs. The ripple marks are straight to locally branching, and there are some interference patterns. The crests trend about 070° and 130°.

Interpretation of lithofacies N: The fine textures, thin planar stratification, fine grain size and halite pseudomorphs suggest that this facies was largely deposited subaqueously in a quiet hypersaline depositional environment. A shallow ponded environment is indicated by an exposure of varicolored mudstones that onlaps the edge of a bar-shaped sand deposit (see Section F, Figure 29 and Figure 30b), and by the association with rippled sandstone and mudcracked black shales. These two types of sedimentary deposit suggest that the ponds lay behind distributary channels or barrier sand bodies and were flanked on their landward edge by mud and sand flats resembling modern tidal flats (Reineck and Singh, 1975). Steady strong winds, which are known to drive water onto modern deltas (Oomkens, 1970) and mudflats (Schneider, 1975), were probably the main control of flooding, ripple generation (Tanner, 1967; Harms, 1969), and dessication of the landward, muddy sand flats. The rarity of mudcracks in the laminite units suggests that the ponds were not often completely dessicated. The basal and topmost development of red color bands supports gradual deepening and then infilling of the ponds. The oxidized red layers were laid down when the ponds were perhaps less than a few centimetres in depth or reduced to a damp playa flat. Darker colored mudstones were deposited in the deeper areas of the ponds. Slumping occurred on gentle slopes.

Fine halite and gypsum pseudomorphs imply the ponds were perenially or periodically hypersaline. Laminae, composed mostly of 1 mm crystals, suggest precipitation and settling in the pond waters (Shearman, 1970), but large crystals scattered randomly in the mudstones may have formed by displacive growth (Smith, D.B., 1971; Shearman, 1978; Kendall, 1979a). Scarcity of evaporite minerals in the darker color bands implies dilution of pond waters by flooding, although it is possible that the gypsum was removed by sulphate-reducing bacteria which would have thrived in the anoxic waters indicated by the black mudstones (cf. Neev and Emery, 1967).

(O) Halite-bearing siltstone-sandstone lithofacies

Description of lithofacies O: This facies includes muddy siltstones, coarse siltstones and very fine sandstones that are rich in small cubic molds after halite crystals (Plates 91 and 92); most of the rocks are brown, but some of them are gray and green-gray. The facies occurs in 1 to 7 m thick units that are intercalated with varicolored mudstones (Section A, B, C and D, Figure 29) in the section below Fischells limestone on Fischells Brook, and also in continuous, though poorly exposed, sequences several tens of metres thick (Figure 29, Section A).

The facies includes several types of deposits. Brown, massive, muddy siltstone is the most common rock type (Plate 91). It occurs in beds, 50 to 500 cm thick, lying in many cases gradationally within varicolored mudstones. In some units, thinly developed, drab gray, massive, silty mudstones lie between the varicolored mudstones and the brown siltstones. Cubic crystal molds, 1 to 5 mm in size, are distributed randomly throughout the mudstones.

The second type of deposit consists of sequences, 2 to 6 m thick, composed of graded beds of coarse siltstone and structureless, halitic, muddy siltstone. The coarse siltstones overlie a basal scour. Internally some of them have a thick interval of planar lamination without parting lineations, and this is overlain by a thin division with cross-lamination. Others have only ripple laminations, including some climbing types. Crossbeds occur locally. Some of the halitic muddy siltstone beds have indistinct bedding, and symmetrical convolute deformation, picked out by weathering, was noted locally (Figure 29, Section D).

The third type of deposit in the facies consists of brown, silty, very fine sandstones, 1 to 4 m thick. They have scoured bases, abundant internal erosion, some trough cross-stratification, plentiful ripple cross-lamination and some climbing ripple drift. They also occur as sheet-like deposits of planar lamination with current lineations overlain by ripple drift. Silty sandstones that overlie both the rippled sandstones and mudcracked black shales of lithofacies N (Figure 29, Section A; Plate 92) are made up of a series of convex-upward wedges, 45 cm thick and several metres long. The wedges are constructed of crossbeds, with cross and some planar lamination. They are stacked so as to offlap each other from east to west along the outcrop. Cross-lamination in the wedges has a west to northwest paleoflow and current lineations on the planar stratification gives northwest-southeast flow trends.

Interpretation of lithofacies O: The various sediments of the facies are interpreted to have accumulated on a playa mud-flat which lay landward of the hypersaline ponds (lithofacies N). The massive muddy siltstones were laid down in distal areas of the mudflats, near pools; halite crystals were precipitated from saline groundwaters and grew displacively in the oxidized brown muds (cf. Smith, D.B., 1971; Shearman, 1978). The sheets of silt and very fine sandstone were deposited by shallow, ephemeral streams in the mid-part of the flats. Deposition was probably rapid with suspended sediment laid down as climbing ripple drift (McKee, 1965; McKee et al., 1967).

The thick sandstones with crossbeds and abundant scour and fill formed in ephemeral braided stream channels (Picard and High, 1973; Tunbridge, 1981a and b) that fed sand- and mud-size detritus to the mid and lower part of the mudflat. The convex-upward, offlapping sandstone wedges prograded over the marginal, muddy sand flats of the hypersaline ponds and were perhaps deposits of small aeolian megaripples that encroached along the edge of the ponds.

(P) Green-gray mudstone-siltstone lithofacies

Description of lithofacies P: Lithofacies P consists of green and green-gray mudstones and siltstones that are found only below the Fischells limestone on Fischells Brook. They occur in units 1 to 3.5 m thick mostly associated with rocks of lithofacies Q.

Lithofacies P has three associations. The first association consists of massive green-gray mudstones, up to 240 cm thick, gradationally overlain by 27 to 45 cm of current laminated, green-gray siltstones. The latter in turn underlie lithofacies Q sandstones to form coarsening-upward sequences overall (Figure 29, Sections B and C). Climbing ripple drift, ripple cross-lamination, and local convolution are typical of the upper siltstones; downcurrent the ripple drift passes into small scale crossbeds. Large, sand-filled cracks were noted in a mudstone unit that lies sandwiched between two thick lithofacies Q sandstones.

The second type of deposit is composed of 20 cm beds of interlaminated green-gray siltstones and mudstones, with some beds of green and gray massive mudstone.

The third association in this facies consists of graded beds, 30 to 90 cm thick, of siltstone and mudstone. The siltstones, which are mostly 5 to 20 cm thick, lie sharply or erosively upon the mudstones and have ripple cross-lamination, some climbing ripple-drift, and flat to wavy thin stratification. They grade up into structureless mudstones. The current bedded siltstones decrease in thickness up through the sequences, some of which have mudcracks and reddening at their top.

Halite crystals are absent in the facies except where the section lies below the lithologies of facies N and O, as in Section C, Figure 29. Here halite occurs at the base of a green - gray mudstone bed.

Interpretation of lithofacies P: The drab-colored mudstones and siltstones of this facies, which are found only below the Fischells limestone, are interpreted to have been deposited in different delta subenvironments. The subenvironments included sheltered, shallow bodies of water associated with small, nontidal, fluvial-dominated deltas, and the subaerial delta plain environment where sediments were poorly drained and hence permanently waterlogged (Donaldson et al., 1970; Leeder, 1974; Ryder et al., 1976).

The first association of mudstones that grade up into current ripple-bedded siltstones is interpreted to have formed in front of distributary sand bodies. Rapid deposition is indicated by lack of structure in the basal muds and the presence of climbing ripple drift (McKee, 1965) in the siltstones. Similar deposits have been reported in the Salton Sea ahead of bar finger sands of the New River Delta (Stephen and Gorsline, 1975). Finely laminated silts and muds of the second association were deposited by overbank flooding (Kanes, 1970; Donaldson et al., 1970; Elliott, 1975) in shallow sheltered bays and ponds on the delta top.

In the third association, decelerating density currents were probably responsible for the grading and sequential arrangement of cross-laminated siltstones below structureless muds. The currents probably formed when sediment-ladden flood waters descended through levee-breaches from elevated, distributary channels. Their suspended sediment was spread out as crevasse splay lobes or sheets into nearby bays or lakes (Elliott, 1975). Overbank flooding and channel crevassing higher on the delta plain produced similar graded deposits which were partly oxidized.

(Q) Crossbedded sandstone lithofacies

Description of lithofacies Q: Green-gray, very fine to medium-fine grained sandstones, in units 2 to 8.5 m thick (Plate 93), compose this lithofacies. Sandstones dominate two separate sections (Figure 29, Sections B and D) along Fischells Brook below the Fischells limestone. Each section is 30 to 40 m thick. A single unit, 8 m thick, occurs in the Mollichignick Member (Plate 83; Figure 27, Section B). Grain size within individual sandstone units may be constant or it may fine upward. Some sandstones are composed of interbedded, lenticular sandstones and siltstones.

Characteristic of the facies as a whole, but particularly the ungraded sandstones, is the abundance of internal scouring, intraclasts and large, trough cross-sets. The latter can reach 50 to 150 cm in thickness. Large, planar crossbeds are common near the base of some units and may be interlayered with planar-stratified beds toward the tops of many units. Ripple cross-lamination and climbing ripple drift and convolution of sedimentary structures also occur. Parting lineations associated with the planar stratification, pockets of carbonized plant fragments and mica-rich layers are common. Most basal and internal scours are irregular, although some are planar on an outcrop scale. In the scour hollows are pebble lags of green and/or red intraclasts that include blocks of siltstone up to 30 cm in size. Imbrication of intraclasts at the bases of some units gives an apparent southward paleoflow direction. Intraclasts are also concentrated along trough scours and foresets. Steep, curved foresets and scoop-shaped scours are characteristic of many trough crossbeds. Some of these crossbeds have several erosion (reactivation) surfaces, each subparallel to the original scour and each overlain by a number of foreset laminae. Apparent reversal of crossbed direction has been noted in several sandstone units. This reversal commonly occurs above scours that have eroded previously deposited trough crossbedded and planar-stratified sandstones (Figure 30A). The paleocurrent directions indicated by the crossbeds are, however, dominantly to the south and southwest (Figure 32).

Scour and fill is typical of units that are composed of lenticular interbeds of sandstone and structureless siltstone. Sandstones, 70 cm thick, are enclosed in shallow, broad scours which cross cut both previously deposited sandstones and interbedded green shaly siltstones. Planar stratification overlain by trough cross-stratification generally composes the scour-based sandstones.

In sandstones that fine upward, there is a corresponding decrease in the size of sedimentary structures. The lower parts of the units have large, trough cross-stratification, while in the upper parts there is planar lamination, ripple-drift cross lamination and small scale, symmetrical and overturned convolution. The sandstones mostly pass up into red, structureless siltstone (comparable to lithofacies A; see Figure 29, Section D). They are also associated with red, fine sandstones and siltstones and some planar cross-stratified sandstones and siltstones that bear a striking resemblance to deposits of lithofacies B and lithofacies D along Robinsons River (Figure 23, Section D).

Closely resembling the ungraded and fining-upward sandstones in color and grain size are sandstones that display well developed planar stratification. One such sandstone occurs in the Fischells Brook section in the transition from the lower sandstone upward into a section comprised mostly of varicolored and halite-bearing siltstones. The planar-stratified sandstones, which are capped by a bar-shaped, crossbedded sandstone unit (Figure 29, Section C, Figure 30B) overlie green-gray mudstones and siltstones (lithofacies P). The planar-stratified sandstones carry consistent parting lineations trending 176 to 356^{o} and are separated into two beds by 15 cm of laminated, red, sandy siltstone. Mudcracked, laminated, red siltstone, 20 cm thick, separates the stratified sandstones from the overlying bar-shaped sandstone body. The latter is incompletely exposed but is 168 cm thick at the centre, tapering to 50 cm in the north; the southern margin is unexposed. It has a flat non erosive base, with sand infilling mudcracks in underlying siltstone, and the top is smooth and convex-upward. In the thickest part of the deposit trough crossbeds give southerly apparent paleoflow directions. At the northern margin of the bar, however, directions are easterly trending, and northward inclined, mud-draped, planar or scoop-shaped scours are overlain by parallel beds (Figure 30B). The northern slope is onlapped by varicolored mudstones and halite-bearing brown mudstones and siltstones.

Interpretation of lithofacies Q: The ungraded and fining-upward units of crossbedded sandstones are probably the deposits of sandy, delta distributary and river channels.

The fining-upward sandstones are dominated by trough crossbedding and are overlain by red, vertical-accretion deposits. These characteristics together suggest that these sandstones are the deposits of high-sinuosity as river channels described by Allen (1965a, 1970a).

The ungraded sandstones, however, are markedly different in that they contain mudclasts and have abundant internal scouring associated with large trough, and some planar, crossbeds. These structures suggest that high-energy flood events repeatedly washed out earlier sand deposits, and then deposited sands in the channel as large bars and sand waves (Harms, 1975). Planar-stratified units with parting lineations were also laid down in the channels when flow velocities increased locally. Waning flow produced current-rippled deposits toward the end of some of the floods. Beds of climbing ripple drift (Jopling and Walker, 1968) near the tops of some of the sandstones indicate that even as current strength was reduced, sediment supply was still high and deposition took place rapidly (McKee, 1965). Thin siltstone layers separating thick sandstone units suggest channels were abandoned or subject to only gentle flow between floods.

The ungraded sandstones occur in some instances as the upper members of coarsening-upward sequences. The sandstones overlie mudstones and siltstones of lithofacies P which are interpreted as prodelta deposits. This suggests that the ungraded sandstones were deposited in distributary channels. There is little evidence within the rock succession hosting these sandstones that tidal or wave action contributed to the character of the succession as a whole. Instead, the channel sandstones clearly have a fluvial aspect. It is probable therefore, that the rivers constructed elongate bar-finger sand bodies to form bird's-foot deltas (Fisk et al., 1954; Coleman et al., 1964; Kanes, 1970; Donaldson et al., 1970; Stephen and Gorsline, 1975). Frequent channel switching and crevassing (Elliott, 1975; Wright, 1976) is common in this type of delta. Evidence that such processes affected the ungraded sandstones of the Jeffrey's Village Member is provided by changes of paleoflow direction in crossbeds associated with major scours. It is supported by abrupt deposition of mudstone or siltstone beds upon large scale crossbeds within the sandstones.

Large mudcracks that occur in siltstones between two thick channel sandstones, suggest that channels were periodically abandoned and desiccated. Similar desiccation features are present in temporarily abandoned distributary channels of the New River delta, Salton Sea, California (Stephen and Gorsline, 1975).

The bar-shaped sandstone which is onlapped by varicolored mudstones and halite-bearing siltstones may also be a distributary channel deposit. The channel, however, would have been abruptly abandoned so that it became the site of a hypersaline pool which was infilled by the onlapping fine beds. Elongate salt pans have been described in an abandoned channel in the Colorado delta, Gulf of

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(R) Marine carbonate lithofacies

General definition of marine carbonate lithofacies: Limestone and dolomite occur in several units, 2 to 8 m thick, within the Jeffrey's Village Member (Figure 31). Marine carbonates in the Mollichignick and Highlands Members are described within lithofacies M. Limestones in the St. George's Bay lowlands, named by Bell (1948), are the Barachois, Fischells (Plate 94), Crabbes (Plate 95), Jeffreys and Heatherton (Plates 102 and 103) limestones. Usage of some of these names has been continued (Figure 31) and unnamed limestones are identified by an initial and number, e.g. JVL-2. The Crabbes and Jeffrey's limestones were considered by Fong (1974, 1975) to be the same unit repeated by faulting; therefore the name Jeffrey's limestone is discontinued. The Crabbes limestone can be correlated northward with units at Sticking Cove and Muddy Hole (Bell, 1948; Fong, 1974; Fong and Douglas, 1975). Fossiliferous limestones in the "round valley", Codroy lowlands and two fossiliferous dolomitic limestones on Barachois Brook are correlated with the Fischells limestone and JVL-2 of the Fischells Brook section.

Carbonate units in the Jeffrey's Village Member consist of argillaceous and silty limestones, dolomitic limestones and dolomites. They are gray, buff or reddish and are interbedded with gray mudstones and/or shales. Individual carbonate beds include mottled lime mudstones, skeletal wackestones and packstones, stromatolitic and algal carbonates, oolitic sandstones, oolitic and pisolitic limestones and calcretes. Limestones have in some instances been replaced by red, vuggy, diadenetic dolomite. Ferruginous limestone breccias (Codroy Breccias, Bell, 1948) occur in the basal 65 m of the member where they are associated with red siltstones (lithofacies A) and some ferruginous sandstones.

There is a gradual change of character in the carbonates through the upper Jeffrey's Village Member as seen along Fischells Brook. Dominantly subtidal carbonates rich in a near-normal marine fauna near the base are replaced upward by oolitic and algal-dominated carbonates. The latter are poor in fauna and are associated locally with evaporites and oolitic limestones with radial and spherulitic ooids. These limestones are extensively dolomitized and have been modified in several units by calcretes; for example, the Heatherton limestone on Fischells Brook is composed of three beds, each consisting of red dolomite overlain by gray calcitic calcrete. Carbonate units such as the Fischells limestone, JVL-2 and JVL-3 consist of subtidal carbonates overlain by intertidal algal deposits that are capped by calcretes and redbeds. The Crabbes limestone is composed of three sequences consisting of shales overlain by interbedded shales and wavy bedded limestones, and capped by wavy-bedded limestones.

Several subfacies occur in the carbonates; viz. (i) burrowed, lime mudstones, (ii) skeletal packstones and wackestones, (iii) algal carbonates, (iv) oolitic carbonates and sandstones, (v) calcretes,

(vi) dolomites and (vii) brecciated limestones. Unlike the approach taken with the other lithofacies in the Robinsons River Formation, each of the subfacies of the marine carbonate lithofacies is described and interpreted separately.

(i) **Description of burrowed lime mudstones:** Lime mudstones deposited in irregular 2 to 10 cm beds are interbedded with gray calcareous mudstones and shales. They generally lie at the bases of carbonate units and are buff weathering, argillaceous and carbonaceous. They contain few fossils, but are mottled by randomly oriented, 2 mm burrows (**Helminthoid**a?). The sparse fauna consists mostly of the bivalve **Aviculopecten** and there are some algal laminae.

Moldic porosity is common and is filled by clear ferroan calcite spar or dolomite. The porosity resulted from dissolution of rhombic to needle-like crystals and of skeletal remains.

Rhombic dolomite crystals 0.02 to 0.05 mm in size are scattered through the lime mudstones.

Interpretation of burrowed lime mudstones: The subfacies was deposited in a quiet subtidal environment that hosted a sparse skeletal and soft-bodied fauna. The environment was probably near-shore shallow lagoons with elevated salinities. Moldic crystal porosity, possibly after gypsum, and fine crystalline dolomite in the lime mudstones suggest that they were affected by sabkha processes (Kinsman, 1966, 1969). The facies resembles facies IV wackestones of south side of Fischells Brook. Those from the Crabbes limestone have been well documented by Mamet (1968) (see Table 6). In the limestones of Fischells Brook, the foraminifera are dominated by species of Biseriammina, but also include Endothyra, Palaeotexturalia, Pseudoglomospira, Endothyranopsis, calcispheres and encrusting Tuberitina (by comparison to Mamet, 1970).

The packstones and wackestones are all recrystallized to varying degrees. An originally micritic matrix is now mostly recrystallized to microspar and is partly dolomitized. In some thin sections, it contains neomorphic stellate spar (Bathurst, 1975). Shell detritus is commonly unaffected except for some micritization, but locally it has been dissolved and the molds filled by spar. Shelter and cavity porosity (Choquette and Pray, 1970) associated with fossils is usually filled by blocky calcite and some ferroan calcite spar.

In carbonate units near "round valley" in the Codroy lowlands, the subfacies is silty and darkened by carbonaceous matter including algal laminae. The latter bind the matrix and encompass the larger fossils to form oncolites (Plate 100). Skeletal grains are predominantly ostracods, but include some crinoids, monocellular encrusting foraminifera, bryozoans, bivalves, brachiopods, branching tubular corals and cephalopods. In one unit of dolomitic packstone, the skeletal components are mostly crinoids and bryozoans. Shell material is selectively replaced by clear spar. Layered, brown, acicular, radial and structureless brown micritic cements encrust skeletal remains (Plate 101). Algal laminations bind skeletal material and lime mud to form small heads 0.5 to 2 cm in width on the outsides of shells in the carbonates in Codroy lowlands. The oncolitic structure is unevenly developed around the shell and includes interlaminar porosity that is now filled by clear spar. Prismatic authigenic quartz is abundant in the cement (Plate 101) and the algal structures.

Interpretation of skeletal wackestones and packestones: The lack of current structures, the interbedded shales, abundance of bioturbation and general poor sorting of these carbonates suggests that they were laid down in a generally quiet subtidal environment. The diversity of fauna and other allochems suggests a number of ecological niches. Packstones dominated by crinoids or a mixed crinoid-brachiopod-bryozoan fauna perhaps accumulated on subtidal shoals that were influenced by current action and had near-normal salinities (Johnson, 1971; Heckel, 1972). Foraminiferid-peloid packstones, however, suggest quieter, more sheltered areas. The foraminifera are dominated by the form Biseriammina which, according to Mamet (1970), is principally found in oolite bank or hypersaline lagoon settings. The subsidiary protozoa are more typical of the lagoonal setting (Mamet, 1970) and the abundance of peloids and lack of ooids in the packstones suggest quiet lagoonal conditions. Chondrites burrows are most common in shallow, subtidal marine environments, but may also occur in nearshore or central areas of lagoons (Chamberlain, 1978). The rock types encompass Schenk's (1969, 1975) facies I wackestones and facies V biosparites (grainstones) which were interpreted as deposits of inner shelf and reef environments.

The facies in the Codroy lowlands was supplied with more extrabasinal silt and mud than the carbonates in the St. George's Bay area. The fauna is quite diverse but is dominated mostly by ostracods. This suggests that it was probably deposited near shore with most skeletal grains carried into the quiet muddy environment from adjacent carbonate-rich areas. Oncolitic algal growths on shell fragments, leaching of shell material, and presence of multiple cements suggest a complex depositional history for some of the "round valley" carbonates. This history included precipitation of fibrous subtidal marine cements (Taylor and Illing, 1969; Friedman et al., 1974), binding of skeletal grains by subtidal algae (Scoffin, 1970; Neumann et al., 1970) and freshwater vadose diagenesis (Longman, 1980).

(iii) **Description of algal carbonates:** Small algal structures, a few centimetres in size, are found as oncolites and small columnar and domal heads in the mudstones and packstones. However, larger algal structures fill complete beds in various limestone units throughout the Jeffrey's Village Member. The deposits are of two types:

a. banks and beds of well developed columnar and domal stromatolites, and flat-laminated algal mat composed of buff weathering, dolomitic, silty and argillaceous micrite.

b. beds of very irregular lumps of dark brown, vuggy dolomite that possess no structure characteristic of laminated, stromatolite buildups, but do include textures of Codacian algae and Serpulid worms.

Stromatolites of the first type are best developed in the Heatherton limestone (Plates 102-103) and in a deposit on Highlands River (Figure 27; Plate 104). Thin developments of stromatolites also occur in several beds, 10 to 35 cm thick, 4 km east of the Trans Canada Highway on Barachois Brook.

The stromatolites of the Heatherton limestone are 1.8 m thick at Rattling Brook but increase to 3 m at Fischells Brook. At Rattling Brook large domal mounds 20 to 60 cm high and up to 4.5 m across occur. The mounds appear to overlap each other and the mound surface is fashioned by individual, asymmetric, inverted cone-shaped heads; these are 10 to 20 cm high and 15 cm in diameter, and form caps to tilted columnar stromatolites within the beds (Plate 103). All the heads have a slight elongation and their steep sides face 320°, 332° and 005° on different mounds. In cross sections of individual beds, the stromatolites consist of columnar structures that lean in a similar northward direction. Traced southward along the Rattling Brook exposure, the heads become rounded. Traced northward to Fischells Brook, they pass into vertically-elongate, smooth, lumpy heads that have been modified by calcrete development. The algal limestones are also extensively replaced by red dolomite.

Microscopically, the heads at Rattling Brook are composed of carbonate that resembles dark, mottled peloid packstone and locally contains ostracod detritus. The peloids, which are 0.05 mm in size, appear to have broken down to micrite locally or pervasively. Some peloids are coated by a fine, radiating, acicular carbonate layer, and fenestral porosity is closed by blocky calcite and ferroan calcite spar.

The algal deposits on the Highlands River consist of two beds of columnar stromatolites, 45 and 58 cm thick (Plates 104 and 105). The stromatolites overlie shales and dolomitic, skeletal and oolitic wackestones and packstones. The columns, which are 5 to 10 cm in diameter, show marked changes of tilt direction between the two beds. The stromatolites are built of buff- and gray-colored laminae that resemble smooth mat in the lower parts of heads and broken smooth mat at the top of heads (Logan et al., 1974); the centres of some heads are locally recrystallized to unstructured microspar. The lamination is formed by mottled micrite alternating with sparry micrite, rich in fenestral porosity. Ooids are locally bound within the lamination. Narrow, circular to bird's-eye shaped fenestra are filled by coarse, blocky spar (0.5 mm size), which coarsens inward from pore margins. Some of the larger pores sheltered ostracods. Lime mud, ooids, skeletal fragments and flakes derived from the broken smooth mat of the top of algal heads fill interstices between the heads.

Flat-laminated stromatolitic carbonates, 30 cm thick, overlie irregular lumpy algal beds at Flat Bay. They are also the most common stromatolite type along Barachois Brook, where they occur only a few hundred metres from the Crabbes Brook fault. At this locality, they are 10 to 260 cm thick and are associated with 10 to 35 cm beds of

SH-C stromatolites, bioturbated lime mudstones and some calcrete (Figure 31). The flat stromatolites are composed of either microcrystalline dolomite (0.03 mm grain size), with partly dolomitized micrite laminae, or dense, peloid packstones similar to those described in the Heatherton limestone; both contain irregular fenestral porosity (Logan, 1974). In algal mats composed of peloids, the lamination is picked out by size sorting of peloids, and by concentration of silt-sized quartz and mica grains. The peloids, which are mostly 0.03 mm and rarely up to 0.4 mm in diameter, consist of dark cryptocrystalline micrite with rather diffuse boundaries. Clear microspar fills the interpeloid spaces.

Lumpy algal carbonates (Plate 106), composed of black dolomite, represent the second type of algal carbonate deposit in the lithofacies. At Rattling Brook and Flat Bay they occur in the Jeffrey's Village Member where they form beds up to 92 cm thick (Figure 31). The beds are composed of brecciated carbonate at the base and nodular to cavernous dolomite upward. Microscopically, the unstructured dolomites are composed of small lumps, 1.5 to 3.5 mm in size, separated by narrow channels and irregular porosity. The lumps are formed of dark cryptocrystalline micrite permeated by 0.03 mm diameter, spar-filled tubules (Plate 107), that are similar to Codacian algae or <u>**Girvanella**</u> (Bathurst, 1975; Scholle, 1978). The lump structure gives way to areas of patchy and mottled micrite associated with a spar-filled ramose pore system (0.15 mm wide). The micrite is replaced by patches of brown, fine, fibrous dolomite.

The lumpy carbonates contain worm tubes which are 0.3 mm in diameter (Plate 108) and have a fine fibrous wall structure similar to *Serpula* (cf. Johnson, 1971). Radial, acicular cement (Bathurst, 1975) fills the tubes, but appears to overprint an earlier, fibrous cement attached to the tube walls. Remaining porosity in the worm tubes and within the algal lumps in general is filled by blocky spar. Broader channels between the algal lumps are locally crossed by 3 mm long, 0.08 to 0.09 mm wide lath-like calcite crystals (Plate 107).

Interpretation of the algal carbonates: The stromatolites were deposited in low to high energy, intertidal settings that included banks and algal flats. Banks of large mounds and columnar stromatolites formed important buildups in JVL-4 and JVL-6 of the Fischells Brook section. The buildups, with their asymmetric stromatolite heads (Heatherton limestone at Rattling Brook) and inclined columns (limestone, Highlands River), suggest high-energy settings. Unfortunately, the areal distribution of the stromatolite deposits and their lateral relationships to other carbonate subfacies is unknown. In most sections, the stromatolites lie above subtidal carbonates and are capped by laminated algal mat, calcrete or red-beds. This may indicate that they were attached to prograding shorelines similar to Shark Bay, Australia (Logan et al., 1974), and that the algal heads and mounds formed on exposed high-energy headlands, where they were fashioned by wave action.

A different environment, however, is proposed for the Highlands River deposit which is associated with the subtidal, lagoonal shales and sandstones of lithofacies K. In this case an algal bank may have formed a barrier behind which a lagoon formed. The growth of inclined columnar stromatolites in the deposit could then have been controlled by tidal currents (Hoffman, 1967, 1976; Logan et al., 1974; Playford and Cockbain, 1976) that flowed in and out of the lagoon, perhaps along tidal channels.

Flat algal mats occur at the tops of some algal banks where they are intercalated with stromatolite heads. They also cap the oolitic and oncolitic deposits of JVL-3 and are common in the most easterly carbonates of the Jeffrey's Village Member along Barachois Brook. They are interpreted as the deposits of sheltered, low-lying areas of tidal flats (Kendall and Skipwith, 1968, 1969; Logan et al., 1974).

The lumpy algal carbonates were built of blue-green algae, resembling modern Codacian algae and the fossil algae **Girvanella**. Curved worm tubes with wall structures similar to Serpula (Johnson, 1971) were also important in the construction of the lumps. Fine, radiating, acicular cement within the worm tubes may be similar to cements of the shallow subtidal deposits of the Persian Gulf (Taylor and Illing 1969; Shinn, 1969) or those found in modern reefs (Land and Goreau, 1970; Friedman et al., 1974; James et al., 1976). However, the lath-like calcite crystals between the lumps resemble the felted crystal fabrics of ancient and modern calcitized sulfate evaporites (Shearman and Fuller, 1969). Since and the lumpy algal beds immediately overlie gypsum and celestite beds, it is probable the carbonates and evaporites were deposited in a shallow, hypersaline, lagoonal setting.

(iv) **Description of oolitic carbonates and sandstones:** This subfacies consists of grainstones and calcareous sandstones that are oolitic or both oolitic and intraclastic. They occur in beds, up to 1.6 m thick, in limestones JVL-3 and 4 of the Fischells Brook sections and in limestones at Muddy Hole and Flat Bay (Plate 109). Dolomitized, oolitic limestones are associated with stromatolites along Barachois Brook.

The oolitic grainstones are intercalated with oolitic sandstones on a centimetre scale. They display wavy and flaser bedding (Reineck and Wunderlich, 1968), lamination and cross-lamination (Plate 109), and have ripple-marked bedding surfaces. The oolitic-intraclastic sandstones are generally laminated.

The oolitic grainstones (Plate 110) consist of brown, well sorted, generally well rounded, fine to medium grained ooids, cemented by clear calcite spar. Sutured, iron-stained grain contacts occur between ooids. Internally, the ooids have a radial-concentric fabric, although some grains have a coarser, spherulitic, radiating texture (Plate 111). Fusion of incomplete or perhaps broken grains is common and it is not unusual to see grains with two or more centres of radial growth (Plate 111). Fine, clear, spar-filled lines are abundant in some ooids, perhaps indicating healing of slightly broken grains. Nuclei are predominantly micrite, but also consist of sparry calcite, terrigenous sand grains and molluscan, algal or bryozoan fragments.

Uncoated quartz grains, some peloids and a few bryozoa fragments are scattered in the grainstones.

The oolitic sandstones are composed of fine grained ooids mixed with equal quantities of quartz and mica, cemented by clear spar. In the sandstone, some of the sand grains are completely coated with micrite (Plate 112), while in others sand grains protrude through the ooid laminae. Micas that have not acted as ooid nuclei have been shredded and enlarged to about ten times their original size by precipitation of microspar cement between cleavage plates.

The laminated, intraclastic sandstones are composed of lithoclasts, mollusc and ostracod shells, coated sand and skeletal grains, and a few poorly shaped and incomplete ooids. The lithoclasts, which are up to 6.8 mm long and 0.18 mm wide are composed of dark, carbonaceous, dense micrite similar to the stromatolitic carbonates. The lamination is produced by the alternation of poorly sorted, intraclastic and skeletal fine sandstones with better sorted, very fine sandstones that have a sparry cement.

Interpretation of oolite carbonates and sandstones: The presence of well sorted, spar-cemented, oolitic grainstones and oolitic sandstones suggests that high energy shoals, tidal deltas or beaches occurred in the marine environment. Terrigenous sands transported into the high energy settings became nuclei for the ooids. Uncoated sand grains together with mature ooids suggest near-shore terrigenous sand was continually supplied to the ooid shoals. Ooids swept from the shoal areas were mixed with platy lithoclasts that were derived by erosion of an intertidal algal mat in adjacent quiet, lagoon or tidal flat areas. Where oolitic sands became stabilized, they were subject to cementation.

The ooids have well developed radial fabric and include coarser spherulitic grains. These ooids are typical of ooids that form in hypersaline environments such as Great Salt Lake (Sandberg, 1975; Halley, 1977), Persian Gulf (Purser and Loreau, 1973) and saline pools of the Gulf of Aqaba (Friedman et al., 1973). Nonetheless, Sandberg (1975) has cautioned against using them as a diagnostic indicator. However, ooids according to Halley (1977) formed in hypersaline environments are generally weak and easily broken by agitation. The frequent occurrence of hairline fractures in ooids and of fragmented and healed broken ooids in the Jeffrey's Village carbonates indeed suggest they were brittle and supports a hypersaline setting. The facies is equivalent to facies III oosparites of Schenk (1969, 1975), who also interpreted them as ooid shoals.

(v) **Description of calcrete:** This lithofacies is formed of gray and red, very finely laminated, massive, nodular and lumpy dense micrites and dolomites. They replace algal limestones and skeletal packstones particularly near the top of carbonate units.

The most spectacular example of calcrete is developed in the Heatherton limestone on Fischells Brook. Here the calcrete has replaced the original stromatolite heads so that they now consist of vertically elongate lumps which have smooth, rounded, protuberant form and a fine curvilinear striation on outer surfaces. The internal structure of the heads can be seen in slabbed samples and some planed-off outcrops (Plate 113). It consists of a core of peloid-micrite with laminar and/or irregular fenestral porosity (Logan, 1974), surrounded by an outer dense, finely laminated, cryptocrystalline limestone cap. Laminar structure decreases into the stromatolite heads and the inner surface of the laminar cap is undulose to micro-nodular.

In the exposures of the Heatherton limestone on the north bank of Fischells Brook, the lumpy calcretized stromatolite bed overlies two beds of red dolomite that are separated by laminar and structureless micritic calcrete.

Red laminated calcrete occurs in the upper beds of the Crabbes limestone at Robinsons Head. The laminae may be poorly developed or may form fine, flat, dense layers up to 1 cm thick. Nodules consisting of laminar structure around a porous, hematitic dolomite core also occur. The laminar structure of the nodules is composed of very fine dolomite that is smooth to microcrinkly. Locally, laminated structures resembling stromatolite hemispheroids project downward into the packstone beneath the nodules. Within the nodules, hematite masks the fine dolomite matrix, but even where iron content is low, the matrix is clouded and dense. Skeletal remains were either obliterated, or leached and replaced by mosaic spar within the nodules. A few ostracod shells have been preserved in one corner of a large nodule. Irregular porosity and rhombic to lath-like molds that have the shapes of gypsum crystals are common within the nodules. Examination of the lower side of the nodules in reflected light reveals incipient laminar growth, faint iron coloration, and gradual decrease of the clouded appearance down into the underlying packstone.

Nodular calcrete, with oncolites and pisolites (Steel, 1973), occurs in a unit along the North Branch of the Grand Codroy River near "round valley" (Plate 114). It has developed on the top of both a dolomitized, burrowed, crinoid-bryozoa wackestone and quartzose sandstones.

Interpretation of calcrete: The structures and texture of these microcrystalline limestones and dolomites are consistent with those of calcretes. Laminar and porous-laminar structure is common in modern (Multer and Hoffmeister, 1968; James, 1972; Read, 1974, 1976; Robbin and Stipp, 1979) and ancient (Bernoulli and Wagner, 1971; Wall et al., 1975) calcretes. Pisoliths and nodular structure in some of the deposits is similar to structures found in modern and ancient caliches (Gile et al., 1966; Reeves, 1970; Steel, 1973). Their stratigraphic position, at the top or in upper beds of carbonate units that are overlain by redbeds also supports the interpretation of these rocks as calcretes.

Laminar calcretes are indicative of soil development (Multer and Hoffmeister, 1968) in semiarid climates or in climates where high humidity alternates with high evaporation rates (Read, 1976). They form generally by leaching of carbonate and precipitation of cryptocrystalline calcite crusts (Read, 1976) in the vadose zone. In the carbonates of the Jeffrey's Village Member, the laminar carbonates range from surficial crusts or rinds on top of stromatolite heads or exposed packstones, to well developed calcretes that modified greatly the original stromatolitic limestones. The diffuse, incipient diagenesis beneath the laminar and laminar-nodular crusts in the packstone of the Crabbes limestone indicates the calcrete developed by downward percolating vadose waters. The laminar structure advanced upward (Multer and Hoffmeister, 1968) after the substrate was plugged (Read, 1976).

Seawater flooding or salt-spray wetting of exposed limestone surfaces may have produced the dolomitic calcretes of the Crabbes limestone. Here hypersaline vadose diagenesis (Scholle and Kinsman, 1974) affected the exposed limestones. The restriction of the gypsum molds to the nodules in the dolomite crusts may reflect the development of a saline microenvironment within the nodules, and so indicate early plugging of the profile. Dissolution of both skeletal grains and gypsum in the packstones suggests later dissolution by freshwater.

The alternation of brecciated red dolomite, capped by laminar, gray calcitic calcrete in the Heatherton limestone suggests a complex history of carbonate deposition and diagenesis for this unit.

(vi) **Description of dolomites:** Dolomitization of the carbonate units in the Jeffrey's Village Member is variable. It has formed small dolomite crystals scattered through many of the limestones, while in other cases the original carbonate has been completely replaced by 0.05 to 0.2 mm crystalline dolomite. The most spectacular dolomitization occurs in algal limestones of the St. George's Bay area where limestones gradually give way downward into cavernous, rubbly and red-colored dolomite. The red dolomite is capped by laminar calcitic calcrete in the Heatherton limestone.

Interpretation of dolomitization: Dolomite is widespread in Windsor Group carbonates of Nova Scotia (Schenk, 1969) and is believed to have formed relatively early in the history of the carbonate. Some of this dolomitization has been already ascribed to sabkha diagenesis (see lime mudstones). Much of the advanced dolomitization, however, may have occurred by mixing of fresh and saline solutions in the shallow subsurface (Badiozamani, 1973) rather than in the sabkha environment. This is suggested by the downward increase in dolomitization of such beds as the Heatherton limestone. It is also supported by the general lack of evaporite mineral growth in and associated with the limestones.

(vii) **Description of limestone breccias:** Several limestone breccia beds occur in the basal 56 m of the Jeffrey's Village Member, along the coastal section near Woodville, Codroy lowlands. They are 25 to 322 cm thick and include the Codroy Breccia (Bell, 1948). They are associated with red siltstones and ferruginous sandstones. The breccias also occur at Ship Cove, on the south side of round valley, and are known from float in synclines that are cored by Codroy strata in the Anguille Mountains.

The limestone breccias from Woodville (Plate 115) consist mostly of ungraded beds, 10 to 40 cm thick. Some thin beds, however, are graded, while others consist of alternating breccia (10 to 29 cm) and ferruginous sandstone (4 to 14 cm). Crude crossbedding with foresets graded from breccia to sandstone occur in one bed in the 'Codroy Breccia'. The bases of breccias either are sharp upon siltstone or gradationally overlie it. The breccias contain angular lithoclasts, 1 to 3 cm in size, set in a matrix of yellow weathering, ferruginous, silty micrite (Plate 116). Lithologies of breccia clasts include lime mudstones, algal carbonates, skeletal packstones, peloid wackestones and oolitic grainstones (Plates 117-122). The major skeletal grains are crinoids, some of which are hematized; bryozoa, which may include ramose and tabular types; ostracods; and some bivalve and gastropod debris. Crinoids (Plate 117) also occur as individual grains with syntaxial crystal overgrowths. Individual ooids are scattered in the breccias.

Algal carbonate lithoclasts have structures similar to the Codacian algae of the lumpy algal carbonates (Plate 122). Serpulid worm tubes (Plate 122), filled by radiating fibrous cements, are also common in lime mudstone or peloid packstone fragments; brown radiating fibrous calcite that appears to have replaced lime mudstone also occurs in the serpulid lime mudstone fragments. There are also many pisoliths (Plate 117) and angular lithoclasts (Plate 120), with both radial and concentric layering separated by local discontinuities.

The breccias in the Anguille Mountains are composed mostly of fragments of lime mud, and serpulid lime mudstone; minor components are grains of oolitic grainstone, crinoid ossicles and pisoliths. The proportion of grains to matrix in the breccias is greater than at Codroy and there is little cementation. Very coarse grained sandstone partings occur in the breccias.

The matrix and clasts in all the breccias are commonly stained with limonite and hematite. Some of the skeletal grains and a few of the larger intraclasts, as well as parts of the matrix, have been completely replaced by hematite. Sparry calcite has cemented fracture and inter- and intra-particle porosity.

The ferruginous sandstones are rarely thicker than 50 cm. They are generally poorly bedded and overlie the breccias either sharply or gradationally. Rare fossil fragments occur in the sandstones. Structureless red siltstones occur either in 29 to 460 cm thick beds that overlie the sandstones in the upper part of the section or lie as poorly defined layers within the main "Codroy breccias".

Interpretation of the limestone breccias: The genesis of the subfacies is clearly a complex problem. The breccias are derived from marine carbonates, but there is no evidence of interbedded evaporites. They are not, therefore, collapse breccias formed after dissolution of evaporites. In the Anguille Mountains the clasts are dominantly of one type, lime mudstone, but in the Codroy area they include sediments from a wide variety of marine carbonate environments. The clast variety probably reflects the local variety of original rock types, and the contrast between the two areas is interpreted as an indication of minimal transport. Fibrous cement in lime mudstones and serpulid worm tubes indicates marine diagenesis before brecciation. The ooliths and clasts with both radial and concentric laminations resemble cave pisoliths (Bathurst, 1975) and may indicate that brecciation was also preceded by freshwater vadose diagenesis. The ferruginous red siltstones that are associated with the breccias are similar to "terra rossa" deposits, and supports a karstic origin for the breccias. Locally, marine or fluvial currents may have caused reworking to produce a greater degree of sorting.

Wall et al. (1975) described limestones in the Carboniferous of Kentucky that are interbedded with fine redbeds and have a similar history of karsting, brecciation and soil development.

(S) Evaporite lithofacies

Description of lithofacies S: Gypsum, anhydrite, halite, potassic salts and celestite occur in the Jeffrey's Village Member in the St. Georges Bay area. Salt deposits probably also underlie the area of Little Codroy River near St. Andrew's in the Codroy lowlands (Hooker Chemical Corporation, 1971).

Gypsum occurs at Plaster Cove and in association with limestones and celestite at Rattling Brook, near Heatherton. These two deposits form gypsum zones C and D of Bell (1948) respectively, but unlike the basal zones A and B of the Codroy Road Formation, appear to be restricted in distribution.

Zone C gypsum at Plaster Cove is 45 m thick (Bell, 1948). It consists of coarsely crystalline, selenitic gypsum that is overlain by red siltstones. The gypsum overlies laminated and cross-laminated green sandstones, and laminated and massive gray siltstones.

Zone D gypsum occurs in two beds, each 2 to 3 m thick, on the coast at Rattling Brook. The beds are intercalated with algal dolomites and limestones, red sandstones and siltstones, and a bed of celestite (section K, Bell, 1948); the sandstones are fine to medium grained, well sorted, and crossbedded and laminated. The gypsum is white to reddish, finely crystalline and encloses numerous, floating 1 cm gypsum crystals (Plate 123). Thin beds of gypsum with red shale partings and streaks occur at the base and are overlain by massive gypsum. The massive bed contains radiating chevron structures 10 to 20 cm in diameter (Plate 124) that resemble deformation structures described from the tectonized Messinian evaporites of Sicily and the gypsum deposits of Nova Scotia (Schreiber et al., 1976). A smooth to mammilated crust of dolomite caliche, 2 cm thick, caps the red sandstones that underlie the gypsum.

Dappled gray and white celestite occurs in a bed 45 cm thick at Rattling Brook (Figure 31). It is variously fine and coarsely crystalline with intergranular porosity, and the textures resemble those of intensely dolomitized carbonates described by Beales and

Oldershaw (1969). Fine detrital mica and quartz and some fine rhombic dolomite occur in the celestite.

The halite deposits of the formation are known only from exploration drilling at three localities near Fischells Brook, St. Fintan's and Robinsons (Hooker Chemical Corporation, 1968a, 1972, 1973). Salt is also suggested by a number of low gravity anomalies in other areas of the subbasin (Figures 33 and 46) (Hooker Chemical Corporation, 1968b, 1971). Halite is associated with anhydrite and gypsum and is interbedded with fine grained siliciclastics. Sylvite, carnallite and polyhalite also occur with the halite. Well bedded deposits occur at St. Fintan's and Robinsons where the salt sections are 120 and 180 m thick respectively; a thinner sequence of salt (54+ m thick) also occurs beneath the main salts in the Robinsons drill hole. The salts are thicker (390 m+) and cleaner at Fischells Brook, and this may reflect a longer period of salt accumulation although the thickness at this locality may well have been increased by salt tectonics.

Salt beds in the St. Fintan's and Robinsons deposits are never greater than 3 to 4 m thick. They are white, neutral, gray, pink or red in color and some units are color-banded. Clean salt with less than 5% impurities and 'dirty' salt both occur. The potassic salts are contained at several levels in the St. Fintan's and Robinsons deposits but are found near the top of the Fischells Brook deposit, where sylvite layers 2 to 5 cm thick alternate with the halite. In most occurrences in the other two holes, the potassic salts are intergrown with halite in the salt beds, and polyhalite occurs both in the salt beds and interbedded with mudstones in the Fischells Brook and Robinsons deposits. Anhydrite and gypsum form up to 25% of individual salt beds, where they may occur as disseminated crystals, clots, angular chunks and blebs (Hooker Chemical Corporation, 1968, 1973). The clots, which may imply nodules, are up to 10 cm in diameter and enclose shaly impurities. Beds of anhydrite, 5 to 10 cm thick, also occur and these enclose cubic crystals of halite; anhydrite occasionally rims salt crystals in the salt beds. The deposits become richer in sulfates with depth and in the Fischells Brook drill hole, sulfate-rich salt sections with up to 40% anhydrite and/or gypsum alternate with sulfate-poor salt sections.

The clastic rocks associated with the salt occur as blebs, streaks, partings, beds or sequences up to 6 m thick. They are gray, green-gray or black calcareous shales and mudstones. Thicker beds frequently enclose nodular(?) anhydrite (the 'swells' of Hooker Chemical Corporation, 1973). Other sediments are red siltstones and brown, fine dolomite.

Interpretation of lithofacies S: The salt and sulfate deposits of the Jeffrey's Village Member are generally poorly known. Interpretation of their origin thus relies heavily upon the associated lithofacies and the general position in the succession.

The salt deposits formed in several large, isolated or inter-connected, subsiding depressions (Figures 33 and 34). The salts are believed to have been precipitated at the same time halite-bearing, fine siliciclastics (lithofacies N to Q) of the lower Fischells Brook section were being laid down farther to the north. They were thus probably deposited in salinas that were surrounded by a complex of evaporitic mudflats and shallow hypersaline ponds (lithofacies N to Q). This implies that the depressions formed basins with restricted connection or periodic cut off from the main marine basin. The stratified, 'dirty' salt and mud deposits of the St. Fintans and Robinson deposits support this concept; the salt beds were precipitated during repeated marine flooding and evaporation, but were subjected to intervals of high terrigenous input. Cleaner, thicker salt in the Fischells Brook deposit possibly formed in an isolated inner basin with only minor accumulation of terrigenous fines. Passage upward from sulfates to halite and then halite and potassic salts in this deposit suggests gradually increasing salinities with time.

In the upper half of the member, gypsum beds are associated with algal carbonates and redbeds. They appear to be limited in areal distribution. This suggests that they probably accumulated in hypersaline pools (Friedman et al., 1973) or in coastal sabkhas behind shoreline barriers such as described by Levy (1977a) on the Sinai Peninsula.

Paleocurrents of the Robinsons River Formation

Description of paleocurrents: Paleoflow trends northwestward and southwestward occur in nonmarine lithofacies of the Robinsons River Formation.

A disperse, radiating, fan-shaped distribution with a northwestward vector occurs in alluvial fan deposits along the southeast margin of the subbasin in the Mollichignick and Overfall Brook Members (Figure 32C). At Flat Bay, a polymodal radial distribution (Figure 32A) is found which is related to the interference of overlapping alluvial fans that lay along the northern, northeastern and southeastern margin of the narrow, northeastern closure of the subbasin (see lithofacies E). No paleocurrents were measured in the pebbly arkoses of the Brow Pond lentil.

Basinward of the marginal alluvial fans, paleoflow associated with braided streams and sheetflood deposits in the Mollichignick Member has a pronounced mean southeast to northwest flow vector defined by parting lineations and trough axes. Ripple cross-lamination and crossbeds give a more radial distribution around the northwestward vector. The rose diagrams of these structures (Figure 32C) also suggest a secondary northeast-southwest paleocurrent trend, which is supported by the few parting lineations.

In the Jeffrey's Village Member, current directions are not so strongly oriented but data indicates both a northwestward vector and southwesterly to westerly paleoflow (Figure 32B). Paleoflow in channel sandstones is dominantly northwestward with a secondary flow to the southwest. The latter is important in sheet-like sandstones of lithofacies B interpreted as shallow, ephemeral braided stream deposits located on a distal alluvial plain. In these sandstones, the same vector is shown by both parting lineation and current-ripple directions.

Southwestward paleoflow along the subbasin axis predominates only in fluvial deposits of the Highlands Member (Figure 32B).

Paleocurrents in marine lithofacies of the Robinsons River Formation are fundamentally different from those of nonmarine rocks. The former fall into two categories; the first associated with deltaic sediments and mudrocks of the lower part of the Jeffrey's Village Member and the second associated with lithofacies L and M in the upper part of the Jeffrey's Village Member and in the Mollichignick Member.

In the lower Jeffrey's Village Member, sands deposited by fluvial-dominated distributary channels prograded south to southwestward. Some crossbeds in the sandstones however suggest that a northeast to eastward vector is present. This would give a bipolar distribution and suggests tidally influenced deltas (Wright, 1978). Paleocurrents in the halite-bearing siltstones and varicolored mudstones give a polymodal distribution. Ripple crests in associated rippled sandstones trend almost due east-west (Figure 32D) and this suggests east-west trending shorelines in interdelta areas in the north of the subbasin at the time of formation.

Straight, wave-formed ripple crests in marine sequences of the upper part of the Jeffrey's Village Member give east and northeast crest trends in the central part of the St. George's Bay lowlands and southeast to east crest trends in the north. Current-ripple bedding associated with parting lineations in shoreline sandstones all give a pronounced southeastward paleoflow, directly opposite to that found in associated fluvial strata and generally perpendicular to the ripple-crest trends (Figure 32D). This suggests shorelines were parallel to the general outline of the present subbasin and currents were generated by onshore eastward-directed waves or currents. Pronounced southeastward paleoflow of current indicators also occurs in the marine siliciclastics of the Mollichignick Member.

Interpretation of paleocurrents: The interplay of marine, lacustrine and fluvial environments each affected the paleoflow distribution within the subbasin. When marine or lacustrine transgression flooded the subbasin, baselines moved close to the basin margins so that streams flowed but short distances perpendicular to and generally northwestward from the basin margins to the water body. Lakes and seas, however, retreated as alluvium prograded into the subbasin and the floodplain widened. At times marine conditions were displaced from at least the present on-shore area of the subbasin, and southwestward fluvial paleoflow was established along the basin axis. Northwestward paleoflow perpendicular to the basin margins was maintained for distances of a few to perhaps 16 km beyond which current flow was redirected southwestward.

Marine flooding of the basin was probably from the west and northwest. Shorelines, suggested by ripple crest trends and predominant eastward direction of current ripple bedding, were parallel to the present basin boundaries.

Paleontology, age and correlative deposits of the Robinsons River Formation

Macro- and micro-fauna and miospores have been recovered from rocks of the Jeffrey's Village and Mollichignick Members.

Shelly macrofossils, foraminifera and conodonts occur in the limestones of the Jeffrey's Village Member. The shelly fauna was collected mostly from the Fischells and Barachois limestones (Bell, 1948; Fong, personal communication, 1976) and the Crabbes limestone (McGlynn, personal communication, 1979) (see Table 6). Foraminifera collected from the Crabbes limestone were identified by Mamet (1968). Foraminifera were also noted in thin section study of carbonate subfacies of the Fischells limestone, limestone JVL-2 (see Figure 31) and limestones in the "round valley" area, Codroy lowlands. They included the forms Biseriammina, Endothyra, Palaeotexturalia, Pseudoglomospira, Endothyranopsis, Tuberitina and calcispheres (after Mamet, 1970). The bryozoa Streblotrypa biformata and the bivalve Aviculopecten were also collected from quartzose sandstones in the "round valley".

Three faunal assemblages were recently proposed for conodonts that occur in limestones of the Jeffrey's Village Member (von Bitter and Plint-Geberl, 1979, 1982). The lower fauna, which occurs in the Barachois and Fischells limestones, is characterized by Taphrognathus n. sp. A. (von Bitter and Plint-Geberl, 1979, 1982) and also includes Cavusgnathus regularis type, Bispathodus sp., Spathognathodus n. sp. A and Spathognathodus campbelli.

The middle fauna is limited to the Heatherton limestone and contains a small form of Cavugnathus windsorensis but excludes Taphrognathus. Von Bitter and Plint-Geberl (1982) used the fauna to correlate the Heatherton limestone with the Black Point limestone of the Codroy area, whereas here, the latter is placed at the top of the Codroy Road Formation, perhaps 1000 m lower in the Codroy Group succession than the Heatherton limestone. Von Bitter and Plint-Geberl's correlation is not accepted on lithological grounds as 'Codroy Breccias' are present above both the Black Point limestone near Codroy, and the Cormorant limestone at Ship Cove, the latter being generally accepted as older than the Heatherton limestone (Bell, 1948; von Bitter and Plint-Geberl, 1982). An environmental control, principally hypersalinity, is rather believed to control the similar faunas of the Heatherton and Black Point limestones. This environmental conclusion is strengthened by the occurrence with both "limestones" of gypsum, codacian algae, serpulid worms and extensive diagenesis of original carbonate mud. Hypersalinity was also used to explain the small form size of C. windsorensis in basal Windsor and Codroy limestones (von Bitter and Plint-Geberl, 1982).

The upper fauna occurs in the Crabbes limestone and in a shale-carbonate-sandstone sequence (Nodesinella band, Bell, 1948) that occurs 100 m below the Crabbes limestone. It contains Gnathodus, G. scotiaensis plus Cavusgnathus regularis type, Hindeodus cristulus and some specimens of C. windsorensis and 'Bispathodus sp".

Macrofauna and microflora, which are scarce and poorly preserved in the Mollichignick Member, are listed in Table 9. Macrofossils were listed by Utting (1966) from two fossil-bearing zones. The lower zone is located on the North Branch River and is said to contain the bivalves Murchisonia? and Streblopteria sp. and the ostracod Glyptopleura sagae. The upper fauna was collected from a number of beds near Limestone Brook and Gillans Island on the Grand Codroy River. It was reported to include the gastropods Bucanopsis sp., Bulimorpha maxneri, Murchisonia gypsea, Murchisonea (Stegocoelia) compactoidea, Naticopsis howi and Platyschisma(?) dubium, the bivalves Edmondia Hartti, Schizodus fundiensis(?), Leptodesma(?) sp., Sanguinolites parvus(?) and Sanguinolites straitogranulatus, the ostracod Paraparchites sp. and the straight cephalopod Michelinoceras(?) vindobonense(?). Recently, a shelly fauna identified by G. McGlynn (personal communication, 1979) was collected on Mollichignick Brook from strata laterally equivalent to Utting's upper zone and also from Utting's locality 2 at Gillans Island. The fauna contained Edmondia hartti, Modiolus hartti, Schizodus cuneus, S. densyi and also unidentifiable brachiopods.

A miospore assemblage identified by Utting (personal communication, 1978) was recovered from Mollichignick rocks immediately beneath the upper faunal beds of Utting (1966). The assemblage included Punctatisporites planus, Auroraspora macra, Rugospora minuta, Verrucosisporites morulatus, Punctatisporites irrasus, Endosporites micromanifestus, Endosporites minutus, Anaplanisporites sp., Lycospora noctuina var. noctuina, Cyclogranisporites sp., Crassispora Trychera, Secarisporites remotus, Knoxisporites stephanephorus, Granulatisporites tuberculatus, Cyclogranisporites palaeophytus, Dictyotriletes cf. D. sagenoformis, Schopfipollenites sp., Retusotriletes incohatus and Spelaeotriletes sp..

No conodonts were retrieved from fossil beds in the Mollichignick Member (von Bitter, personal communication, 1980).

The Jeffrey's Village Member was deposited during a time interval equivalent to subzone B - lower subzone C of the Windsor Group of Nova Scotia. The shelly fauna and lower Taphrognathus conodont fauna recovered from the lower limestones of the Jeffrey's Village Member are both characteristic of Windsor subzone B faunas (Bell, 1948; McGlynn, personal communication, 1979; von Bitter and Plint-Geberl, 1978, 1982). This suggests the succession associated with the Fischells limestone may be correlated in general terms with Windsor Group strata containing the Miller and Maxner limestones in Nova Scotia (von Bitter and Plint-Geberl, 1982).

Foraminifera and the conodont fauna recovered from the Crabbes limestone suggests it belongs to lower subzone C (Mamet, 1968; von Bitter and Plint-Geberl, 1982) of the Windsor Group which contain the Herbert River limestone of Nova Scotia (Moore and Ryan, 1976). The possible presence of Sanguinolites niobe in the Crabbes limestone also supports this age and correlation (McGlynn, personnal communication, 1979; Moore, personal communication, 1978). Conodonts suggest lower subzone C ranges down to the '<u>Nodosinella</u>' band of Bell (1948) some 100 m below the Crabbes limestone.

In the Mollichignick Member, the original identifications of the poorly preserved shelly fauna suggested to Utting (1966) a subzone B age for the member. However, the recent identification of bivalves such as <u>Edmondia hartti</u> and <u>Modiolus hartti</u> support a subzone D age (McGlynn, personnal communication, 1979) for the member which is broadly supported by miospores and ostracods. Utting (written communication discussing the spores, 1978) reported "The presence of a typical Windsor assemblage along with <u>Secarisporites remotus</u>, <u>Schopfipollenites sp.</u>, and undescribed species of <u>Anaplanisporites</u> and <u>Spelaeotriletes</u> suggests that the assemblage may be attributed to Assemblage II found in the Upper Windsor of Nova Scotia (macro-faunal subzones C, D, and E)".

The ostracods recorded by Utting (1966) were assigned a late Chesterian age by comparison to type faunas in the U.S.A. (W. D. Smith, University of Illinois, personal communication, in Utting, 1966).

The subzone D age suggests the Mollichignick Member correlates with the Woody Cape Formation on the coast at Capelin Cove. Both units are thus correlated with an unnamed formation containing the Avon and Meander River limestones in Nova Scotia (Moore and Ryan, 1976).

The Highlands Member overlying the Crabbes limestone is probably of subzone C age. The Overfall Brook Member which occurs 700 m above the last marine fossil-bearing zone in the Mollichignick Member is here placed in the Codroy Group. This is based primarily upon similarity of arkosic lithofacies interbedded in the Mollichignick Member to those in the Overfall Brook Member, suggesting a continuing phase of deposition. It is acknowledged, however, that the Overfall Brook Member may represent the first phases of Cansoan sedimentation, typified in southwest Newfoundland by the Searston Formation as previously suggested by Baird and Cote, (1964), Utting (1966) and Belt (1969).

Depositional environment of the Robinsons River Formation

Discussion of the Robinsons River Formation is complicated by the division of the succession into two geographic areas, the St. Georges Bay lowlands and Codroy lowlands. The exact spatial and time relationship of the Jeffrey's Village and Highlands Members in the north to the Mollichignick and Overfall Brook Members in the south is not clear, although the base of the Mollichignick Member may overlap upper strata of the Highlands Member. For these reasons, the Jeffrey's Village and Highlands Members are discussed separately from the Mollichignick and Overfall Brook Members.

Jeffrey's Village and Highlands Members

The succession in the two members forms a continuum and proceeds through four separate depositional stages. Sedimentation began in the Jeffrey's Village Member with progradation of fine red alluvial sediment from the southeast, and retreat of marine conditions into the northeast of the subbasin. This stage was followed by widespread expansion of shallow evaporitic conditions in the north of the subbasin when fine, drab-colored siliciclastics and several major salt sequences accumulated. The third stage in the depositional history of the area started roughly with the deposition of the Fischells limestone. It consisted of thick nonmarine redbeds in which thin marine sequences were intercalated. The redbeds gradually gained ascendency upwards. The fourth stage occurred above the Crabbes limestone and was confined to the Highlands Member. At this time the axial area of the subbasin was blanketed with abundant red sandy alluvium and floodplain siltstones and coarser pebbly red alluvium was deposited to the northeast and towards the basin margins.

Some general remarks are appropriate:

a) The deposition of the succession occurred in an inherited semiarid to arid, hot climate similar to that of the underlying Codroy Road Formation. Evaporites primarily reflect this aridity in the lower Jeffrey's Village Member. Nodular caliche in fluvial rocks (Gile et al., 1966, Reeves, 1970), calcrete, and carbonates (James, 1972) in the upper Jeffrey's Village Member, together with caliches in the Highlands Member, support continued semiarid climatic conditions after completion of salt deposition.

b) The paleocurrents and lithoclasts in the members indicate that sediment was derived from mountains, north-northeast, northeast and southeast of the subbasin (Table 9 and Figure 32). Three different geological terranes were eroded to supply pebble beds into the Flat Bay area. They were (1) the Cambro-Ordovician platformal and ophiolitic strata of the Humber Arm allochthon highlands to the north, (2) the Fleur de Lys metasediments to the northeast and (3) the volcanic and granitic rocks of the Topsails Igneous Complex and metamorphic rocks to the southeast. The westerly directed paleocurrent data for the remaining redbeds of the Jeffrey's Village Member and the importance of silicic volcanic pebbles in channel sandstones in the axial area of the subbasin suggest that the principal provenance in the upper half of the Jeffrey's Village Member and in the Highlands Member lay to the southeast.

Expected survival distances for pebbles composed of schist, phyllite and limestone transported as river gravel is generally less than 23 km (Cameron and Blatt, 1971). This fact may indicate that the rivers were mostly short, steep-gradient types in the north and northeast, and probably also southeast of the Long Range Fault.

c) Paleocurrent distributions for the Jeffrey's Village and Highlands Members suggest that there were two main paleoflow directions. The first, which is prominently displayed in redbeds of the Jeffrey's Village Member, is to the west or northwest. The second vector is to the southwest along the basin axis. Such paleoflow vectors occur in the deltaic sandstones of the lower evaporitic succession of the Jeffrey's Village Member and in the high-sinuosity fluvial deposits of the Highlands Member.

d) As in the Ship Cove and Codroy Road Formations, marine environments are concentrated toward the northwest. This is supported by the distribution of lithofacies on a broad scale and from features within individual subfacies as follows: (1) at the base of the Jeffrey's Village Member, fine redbeds appear to cover the subbasin from Codroy to just north of Ship Cove; on the other hand, green, gray and black fine grained beds of probably marine origin with only minor brown beds are found in the Fischells Brook area in the north; (2) ripple marks suggest that shorelines were parallel to the present boundaries of the subbasin and paleocurrent directions in marine lithofacies are mostly opposite to those of the alluvial sediments, suggesting marine conditions to the west and northwest and shorelines to the northeast and southeast (see Figure 34B and C); (3) distribution higher in the Jeffrey's Village Member of marine lithofacies and of carbonate subfacies and the orientation of stromatolites suggest that open marine conditions lay to the northwest and shallow quiet shorelines were close to the present basin margins.

During peak flooding of the subbasin, marine conditions extended at least from the northern part of the Codroy lowlands to the region of St. George's, a distance of 75 km. The marine basin probably extended westward beneath St. George's Bay. Marine carbonates form only 8 to 10% of the succession. However, the total succession probably directly influenced by a marine environment is closer to 50%. Of this, 40% occurred in the lower evaporitic section of the member.

With these generalities in hand the four stages of sedimentation for the two members are now assessed.

Stage 1 - Northwestward to westward prograding alluvium composed of lithofacies A and B dominated the basal section of the Jeffrey's Village Member in the south and centre of the subbasin. Drab-colored, fine beds near Fischells Brook suggest that quiet, shallow marine conditions remained in the north of the subbasin during this stage. Several thin carbonates were intercalated at the base of the fine red-beds in the south of the area. These marine sediments represent the last phases in this area of the marine events that had begun during the deposition of the Codroy Road Formation. The carbonates were subsequently karsted during regressions, forming the Codroy Breccias.

Stage II (Figures 33 and 34A) - Stage II encompasses the salt-bearing strata of the St. George's Bay lowlands which occupies the lower 550 to 1,600 m of the Jeffrey's Village Member. Thickness data available (Figure 33) indicate that the salt probably formed in several, rapidly subsiding depressions hosting considerably thicker sedimentary sections. Positive areas separated the depressions and received much thinner sedimentary covers. A topographic high over the site of the present Flat Bay anticline (Flat Bay divide) separated the thinner siliciclastic section at Fischells Brook, west of the anticline, from a thicker salt-bearing depression to the east (Fischells Brook salt deposit). It is also possible that the Anguille anticline formed a similar positive area.

The depressions were possibly isolated from open marine conditions but were periodically flooded as the basin subsided. Alternatively, a restricted connection might have been retained to the Windsor Sea (Bell, 1929, 1948) which probably lay to the west. Shallow salinas were thus maintained in separate, partly interconnected depressions during a common geologic interval or formed at different times as separate areas of the subbasin began to subside actively.

Fine siliciclastics were deposited along the margins of the inland depressions as suggested by the 7 km distance separating the Fischells Brook section from the Robinsons salt deposit. Sedimentation at the basin margins alternated between delta outbuilding and widespread mudflat development. Small, bird's-foot type deltas prograded out into the shallow, sheltered, probably essentially tideless, inland sea.

The lack of salt pseudomorphs in rock sequences related to delta building may imply that a large freshwater inflow occurred. The dimensions of the inland sea probably expanded, and the waters were diluted. This may account for the two salt sequences in the Robinsons salt hole separated by fine siliciclastics, the latter deposited during outbuilding of the lower delta sequence (Figure 20).

Mudflats covered by shallow, hypersaline ponds were established away from active delta areas or when delta growth ceased. Rapid changes of lithofacies such as occur in the Fischells Brook section could be the response to changing climatic conditions. Alternatively, the facies variation possibly involved major shifts of river channel direction (Leeder, 1978) either on alluvial fans or high on the delta plain. Not only would this cause facies changes, but the standing body of water would become increasingly hypersaline as freshwater inflow was cut off. A positive divide might easily have acted as a control for such channel switching. During exceptional floods, rivers discharging from a mountain source to the northeast might escape from existing channels feeding one depression and begin to flow to another area of the same depression or into a separate depression altogether. A recent example of such channel redirection occurred during catastrophic flooding in 1905 near the Gulf of California when the normally southward flowing Colorado River switched its flow northward to the Salton sink (Meckel, 1975; Stephen and Gorsline, 1975) and transformed a playa into a large lake, the Salton Sea. A similar process is envisaged to explain the changeable, vertical succession and the thick, salt-rich sections lying close to, but separate from, thinner, salt-poor sections. The importance of salt in the succession likely reflects arid conditions with very low rainfall and high evaporation (Kinsman, 1969, 1976). The conspicuous presence of delta sands must, therefore, point to a large perennial river carrying only fine sand and mud detritus. It probably originated in a distant mountain source where precipitation was higher and more persistent (Hardie et al., 1978). Petrology of the sands suggests that these mountains contained rocks similar to the Topsails igneous complex.

The salt was deposited toward the centers of the subsiding depressions. The general characteristics of the overall succession in the St. Fintan's and Robinsons salt deposits suggest that the salt formed under generally shallow conditions influenced by terrigenous input. Both sulfates and halite accumulated in the St. Fintan's deposit but gypsum is virtually absent in the Robinsons succession where salt is interbedded with shale. These facts suggest that the salinas were perhaps interconnected so that brine salinity increased and changed in composition from the outermost to the innermost depressions. Deposition of evaporite phases may have been similar to that described in the coastal sabkhas of Sinai (Levy, 1977a and b) and the lagoon and tidal flats of Baja California (Holser, 1966; Phleger, 1969). In the outer water bodies, precipitation of sulfate and halite caused an increase in the brine chlorinity as the less soluble salts were removed. Spillover of this enriched brine into the inner salina occurred during renewed marine flooding. Consequently, halite was precipitated when evaporation resumed and the sulfate stage of precipitation was bypassed.

Shearman (1970) has emphasised the importance of salt redistribution and diagenesis by the action of evaporative pumping of groundwater brines during prolonged periods of evaporation and dessication. Polyhalite, found in the Codroy Group salt deposits, is known to form diagenetically in salt flat deposits of Baja California (Holser, 1966) and suggests that similar diagenetic redistribution of salts occurred in the salt deposits of the Jeffrey's Village Member. The salt deposits probably formed in shallow water salinas with prolonged dessication leading to formation of extensive salt flats surrounded by the saline mudflats.

Stage III (Figure 34 B & C) - Stage III is represented by the stratigraphic interval between the Fischells limestone and the Crabbes limestone. It includes a mixed section of nonmarine redbeds as well as marine carbonates, evaporites and siliciclastics. The stage appears to have two parts; a lower 370 m thick section of regularly intercalated nonmarine and marine rocks and an upper 480 m thick section dominated by redbeds (Figure 20).

In the lower 370 m section as seen on Fischells Brook, redbeds dominated by lithofacies A and D are intercalated with eight dominantly calcareous, marine units. The characteristics of the nonmarine strata suggest that they were deposited on a narrow coastal plain that was crossed by braided river channels. The Flat Bay section, however, indicates that a carbonate-rich coastal playa flat composed of shaly siltstones and flanked by alluvial fans occurred in the northeast of the subbasin. The alluvial fans overlapped each other as they built from the north, northeast and southeast into the narrowing northeast corner of the subbasin. Other alluvial fans lay along the southeast boundary of the subbasin. A major fan complex, the Brow Pond lentil, formed between the Steel Mountain anorthosite and the Long Range fault. Here, active sedimentation probably occurred after a prolonged interval of nondeposition which coincided with tilting and erosion of older deposits of the lentil. The alluvial fan probably then continued to grow during stage IV and perhaps also during deposition of the Mollichignick and Overfall Brook Members.

Old age caliches in red siltstones and thin dolomitic caliches that bounded some of the channel sandstones suggest that active sedimentation was intermittent and little deposition occurred locally upon the floodplain for thousands of years (Allen, 1974; Leeder, 1975).

Although outcrop is generally poor between the marine beds in the lower 370 m section of the Fischells Brook section, it appears that the deposition of the marine strata involved both relatively short transgressive-regressive events (e.g. Fischells limestone and JVL-2) and prolonged marine events. In the latter, marine flooding was maintained after the initial transgression (e.g. JVL-4 and 5, Flat Bay limestone and Crabbes limestone). Transgression over oxidized alluvium was rapid. Regression was effected slowly as marine sediments accreted within the shallow seas and alluvium prograded seaward along the shorelines. Marine flooding occurred from the west and northwest and maximum marine flooding probably occurred in the interval that deposited the Fischells limestone and JVL-2. At this time the inland seas extended at least as far south as the "round valley", Codroy lowlands.

The lowest marine beds (Figure 34B) include the Fischells, Barachois, and JVL-2 limestones of the St. George's Bay lowlands and the fossiliferous limestone of "round valley", Codroy lowlands. They consist of low- to moderate-energy carbonate shelf muds and muddy sand shoals. These sediments were deposited in shallow seas that supported a thriving burrowing fauna as well as crinoids, brachiopods, bryozoa, foraminifera, gastropods and cephalopods. Upward decrease of fossil content and diversity, often restricted to bivalve, gastropod and ostracods, together with the occurrence of thin stromatolites at the top of these carbonates suggests that salinities gradually increased as the seas shallowed.

Oolite shoals and stromatolite buildups typify the middle carbonate units, including the Heatherton limestone. They generally overlie low energy, fauna-poor, subtidal mudstones which lie at the base of most units. Stromatolite banks indicative of relatively high energy environments formed along shorelines or formed barriers behind which shallow, back-barrier lagoons and sandy, tidal flats occurred. Low faunal diversity and abundance, mostly ostracods, bivalves, gastropods and burrowing organisms, plus thin gypsum interbeds and occurrence of radial ooids suggest salinities were higher behind the barriers.

Gypsum, associated with redbeds and lumpy algal dolomites, was probably precipitated in hypersaline pools, lagoons and coastal sabkhas (Friedman et al., 1973; Horodyski et al., 1977; Levy, 1977a and b) that lay behind sand and carbonate barriers. The saline pools and lagoons encouraged formation of the lumpy algal carbonates. Locally, sandy shoreline sequences were also developed. Algal flats developed where siliciclastic detritus was low and the shoreline sheltered and flat.

Shallow seas were microtidal (Davies, 1964) similar to modern inland seas such as Shark Bay, Australia (Hagan and Logan, 1974a) and the Abu Dhabi coast of the Persian Gulf (Schneider, 1975). Tidal currents as well as storm wave action were, however, sufficient to generate high-energy conditions locally within tidal channels and across barriers. They explain the presence of algal banks and local, high-energy shoreline deposits.

The development of calcretes in the upper beds of carbonate units, the widespread dissolution of skeletal remains and the precipitation of blocky spar cements in porosity suggests that freshwater vadose diagenesis was common during the late histories of each carbonate unit. Diagenesis occurred when algal banks and exposed skeletal muds and packstones fell under the domination of meteoric waters as the sea withdrew or evaporated.

In the 480 m of the upper part of stage III, the redbeds are generally much finer grained with thick sandstones only sporadically developed. The fine red alluvium was deposited on an alluvial plain as floodplain siltstones and thin sheet sandstones. The latter are typified by sharp but not always erosive bases, flat bedding and cross lamination. They were probably the flood deposits of shallow, possibly ephemeral, streams (Friend, 1978; McKee et al., 1967; Williams, 1971; Picard and High, 1973) or were produced by sheetwash outward from the lower slopes of alluvial fans (Heward, 1978b; Hardie et al., 1978).

Channel sandstone deposits are not common in the upper part of the stage. They occur most commonly (Figure 20) near the top of the member and as it is traced northeastward. Both low and high sinuosity streams occurred; the low sinuosity stream deposits are dominated by flat bedding. Fining-upward sandstone deposits up to 4 m thick, however, include both crossbedded and planar-stratified sandstones that were probably laid down in meandering channels. If this sandstone thickness represents bankfull channel depth (Leeder, 1973), a channel width of about 40 m and meander belt width of about 390 m (Collinson, 1978b) seems probable. General scarcity of channel sandstones, presence of multistory channel sandstone deposits and locally thick levee and crevasse splay deposits suggest that meander belts were stabilized on the alluvial plain and that the alluvial plain aggraded by overbank flooding. Planar crossbedded sandstones with mudcracked siltstone interbeds suggest that ephemeral braided streams also crossed the alluvial plain. Virtual absence of caliche in the upper section of the stage suggests sedimentation rates were high (Leeder, 1975).

In the upper section of the stage (Figure 34C), only two marine events occurred. These included gray shales and sandstones deposited in quiet lagoons flanked by prograding intertidal flats (Nodosinella band, Bell, 1948) and the final marine event, the Crabbes limestone at the top of the Jeffrey's Village Member. Skeletal and oncolitic lime mudstones and packstones, rich in a foraminiferid fauna (Mamet, 1968) characteristic of open marine biofacies (Mamet, 1970) indicate a return to a less restricted marine environment during deposition of the Crabbes limestone. The characteristics of the marine deposits of the upper part of the stage suggest the seas continued to be shallow and microtidal. The carbonates were also affected by some freshwater vadose diagenesis.

Stage IV (Figure 34D) - Stage IV is confined to the Highlands Member. It consists of repetitive fining-upward sequences of red sandstones and siltstones, deposited by high-sinuosity river channels that traversed a floodplain. Bankfull thickness represented by the thickest channel sandstones of 11 m, suggests large rivers approximately 115 m wide (Leeder, 1973) and meander belt widths up to 1,100 m (Collinson, 1978b).

Mature and old caliche profiles (Reeves, 1970) support a semi-arid climate during this stage for the subbasin and suggest that sedimentation at times ceased for tens of thousands of years in some areas of the floodplain (Allen, 1974; Leeder, 1975). The size of the river channels rules out ephemeral sedimentation. Rather, channel switching by avulsion (Allen, 1965a; Leeder, 1978) probably controlled floodplain and pedogenic development. Thick caliches were developed in abandoned areas of the alluvial system such as interfluvial ridges or elevated alluvial terraces (Allen, 1974; Allen and Williams, 1979) so that meander belts were stabilized for long periods.

In general, the dominance of young pedogenic profiles in red siltstones and the presence of pebble and sand size red mudclasts and nodular caliche intraclasts in channel sandstones suggest that overbank alluvium was steadily reworked as channels migrated laterally. Hence only young pedogenic profiles were able to form. This may imply that the subbasin subsided steadily allowing the rivers to migrate freely across the flood plain.

The reworking of oxidized overbank sediments in large part accounts for the intense red color of the channel sandstones and indicates the early formation of red pigment in the deposits (McPherson, 1980). Sudden and intense flash floods on the flood plain, however, produced channel-bound intraformational conglomerates. This occurred when exceptionally high discharge capable of moving large volumes of detritus washed out both floodplain muds and thick caliche horizons, as is the case in modern semiarid areas (Wolman and Miller, 1960; Baker, 1977). Some of the thicker deposits of this type that occur near the top of the exposed section are ungraded and were probably deposited by larger, longer-lived braided streams.

The presence of the Windsor Sea within or near the subbasin during deposition of the Highlands Member is supported by the two fossiliferous marine units in the lower part of the member.

Mollichignick and Overfall Brook Members

Sedimentation throughout the deposition of the two younger members in the Codroy lowlands is linked to a basin margin setting (Figure 35). This is reflected by the provenance of pebbles, the paleocurrent distributions and the importance of pebbly, coarse, arkosic and argillaceous sandstones of lithofacies E in the succession. Pebbles consisting of plutonic and metamorphic rock fragments support derivation of detritus from a mountain source in the vicinity of the Long Range Mountains. Presence of caliche (Allen, 1974; Leeder, 1975) and spidery plant rootlets (Sargaent, 1975) suggest that the basin possessed a semiarid climate at this time.

Mega- and basin-fill sequences, 400 - 1,000 m thick, of pebbly arkosic sandstones and of pebbly, muddy sandstones formed on alluvial fans adjacent to the active basin margin. The margin lay either coincident with the Long Range fault or more likely to the southeast along shear zones which are known to occur within the Long Range Mountains parallel to the Long Range fault (Chorlton, personal communication, 1980). This is supported by a scarcity, adjacent to the Long Range fault, of exceptionally coarse gravels and debris flow deposits typical of proximal, fan-apex deposits. An elongate aeromagnetic high (Geological Survey of Canada, 1971) occurs between South Branch and Coal Brook suggesting that basement occurs beneath the Mollichignick sediments basinward of the Long Range fault. This implies that the original southeast margin was locally irregular and changed in position as the narrow, fault-bounded basement wedges were uplifted along the active tectonic margin. Alternatively, the magnetic anomaly may imply that some volcanic rocks were extruded close to the Long Range fault within the lower part of the Mollichignick Member.

The alluvial fans of the Mollichignick Member, composed of muddy, brown-red pebbly sandstones, are mostly the products of sheet-flood (Bull, 1972; Heward, 1978b) in a semiarid climate. The fan sequence in the Overfall Brook Member, however, is composed of well washed arkoses which were deposited by braided streams, suggesting increased precipitation in the source area. Abundance of caliche units within the Mollichignick fan deposits, but their absence in the Overfall Brook fans, supports moderation of climate from semiarid to more humid at this time.

The marginal alluvial fans built basinward over axial floodplain deposits; this is clearly seen in the type section of the Mollichignick Member. The alluvial fans influenced paleoflow for much of the succession as sediment was dispersed northwestward from the fan slopes out onto the flood plain by sheet wash and braided streams (cf. Blissenbach, 1954; Hooke, 1967). Periodically, coarse pebbly detritus (lithofacies E) prograded out over the finer alluvium, possibly in response to tectonic uplift (cf. Steel and Wilson, 1975; Steel et al., 1977; Steel and Aasheim, 1978). Alternatively periods of very intense source area precipitation and flooding (cf. Baker, 1977; Heward, 1978a) could have led to fan channel entrenchment and deposition. Fan channels (cf. Bull 1972; Heward, 1978a) were entrenched, and coarse debris was then funnelled as secondary fan lobes out over the toe of the fan and adjacent alluvial plain. Flash floods on the fan itself reworked sediment previously deposited. Such floods caused sheetwash and turned normally shallow ephemeral streams into sediment-laden floods which deposited the fine sand and mud rapidly from suspension as thin, sheet-like deposits (cf. Hardie et al., 1978) as the streams spread out onto the flood plain.

Besides the coarse and fine products of sheetwash that built up the flood plain in the lower 1,000 m of the member, the flood plain was also periodically traversed by large rivers which deposited thick sandstones and overbank sandstones and siltstones. Lacustrine deposits were also an important element of the floodplain. Shallow lakes were sites of bituminuous mud and carbonate deposition with a locally abundant aquatic fauna and flora. Laminated and rippled, micaceous, beach sands and fine, micaceous, carbonaceous delta sands were deposited along the lake shorelines where shallow streams entered the lakes. Marsh flats formed in sheltered quiet areas between deltas and became the sites of paludal mud and carbonate deposition and diagenesis. The thickness of the lake deposits (up to 50 m thick) suggests that the lakes existed for long periods and were of quite large dimensions.

The lacustrine deposits are most common in the lower 1,000 m of the member where they lie together with red floodplain siltstones at the base of coarsening-upward megasequences, tens to hundreds of metres thick. They are overlain by coarser micaceous sandstones and pebbly arkoses deposited by sheetflood and braided streams. These megasequences were probably controlled by higher sedimentation rates on the adjacent Mollichignick alluvial fans and led to sheetflood and distal fan deposits prograding over the lake deposits (Figure 35A).

Approximately 1200 m above the base of the Mollichignick Member, a flat-lying alluvial plain and coastal playa-flat environment developed in this area of the subbasin. Alluvial fan influences upon this flood plain were minor and lakes were apparently absent. Marine flooding occurred on a number of occasions from the west and possibly southwest, where marine deltaic rocks of the Woody Cape Formation were being laid down. Fine siliciclastics and some carbonates were deposited in shallow lagoons and bays. Sandy shorelines formed as marine transgression advanced up to the mountain fronts along the southeastern basin margin (Figure 35B). A fauna of small ostracods and molluscs with fewer small gastropods, inarticulate brachiopods and thin-walled brachiopods suggests brackish marine to slightly hypersaline conditions. Crinoid ossicles in some carbonate and siliclastic beds show, however, that near normal marine floodwaters inundated the low-lying plains. Algal flats developed along the edges of the shallow lagoons as they were infilled or when floodwaters were ponded on the adjacent coastal playa flats. Secondary displacive nodular anhydrite was precipitated locally in the carbonates as the lagoons were finally desiccated.

Following the last marine interval, fine alluvial sedimentation continued on a generally stable flood plain (Figure 35C). Thick channel sandstones, probably, deposits of low and high sinuosity meandering rivers, crossed the alluvial plain. They flowed southwestward (Figure 32C). Although many of sandstone sequences fine upward, some have coarse grained beds at the top of sandstone sequences similar to modern, coarse grained, meandering river deposits (McGowen and Garner, 1970; Jackson, 1975, 1976). Bankfull thickness of channel sandstones of 5 to 6 m gives maximum channel widths of approximately 60 m (Leeder, 1973) and meander belt widths of about 600 m (Collinson, 1978b). Lenticular and sheet-like crevasse splay sandstones (lithofacies B and C) and sandstone deposits of Bijou Creek-type (McKee et al., 1967; Miall, 1978) built up the flood plain.

The presence of thick beds of old age and siliceous caliches (Reeves, 1970) occur in overbank deposits associated with these channel sandstones. This indicates that sediment failed to reach interfluvial areas of the flood plain for long periods (Allen, 1974; Leeder, 1975).

Basin instability increased during deposition of the final 280 m of the Mollichignick Member when sheetflood sands and coarse sandy and gravelly braided streams again carried coarse detritus northwestward into the basin. These deposits formed part of a final, upward-coarsening megasequence that culminated in the outbuilding from the paleo-Long Range highlands, of a major, humid, alluvial fan, the Overfall Brook Member.

Appraisal of the succession in the two members would suggest that two distinct, overall coarsening-upward, basin-fill sequences approximately 1000 m thick infilled the basin. The lower basin-fill sequence was built of a coarsening-upward megasequence that suggests several episodes of source uplift and rapid basinward progradation of alluvial fans into and over lakes on the basin floors. The second basin-fill sequence began with quiet tectonic conditions in the source area which allowed fine sediments to be laid down in a low-lying alluvial and coastal plain. Marginal alluvial fans were generally inactive, pedogenic profiles formed and marine flooding was able to occur. Renewed tectonic activity plus increased precipitation in the mountain source area to the southeast initiated a final phase of alluvial fan outbuilding. This formed a final upward-coarsening sequence that culminated in the well-washed arkoses of the Overfall Brook Member.

Woody Cape Formation

Definition and distribution

The Woody Cape Formation is the name given by Knight (1983) for a succession of green and gray colored mudstones, siltstones and sandstones that outcrop only along coastal exposures from Woodville to Capelin Cove in the Codroy lowlands. The formation is named after Woody Cape and includes strata previously assigned to the Woody Cove beds and Woody Head beds of Bell (1948). These divisions were based upon the presence of thick sandstones and the absence of carbonates in the upper Woody Head Beds. The succession is, however, continuous with no lithological distinctions possible, so that Bell's subdivision is discontinued. Bell (1948) logged detailed sections along the cliffs from Woodville to Capelin Cove (Sections B, C and D) and it is implicit that he considered the succession to be conformable. He did not recognize, however, that the faulted succession in Capelin Cove is inverted. The type section of the formation occurs in a steeply dipping, right-way-up sequence located mostly north of Woody Cape but continues to a small cove just south of the cape. It includes beds 48 to 226 of Bell's (1948) section D. The base and top of the section is fault-bounded. The base, which occurs 500 m north of Woody Cape, is downthrown against redbeds, gray beds and gypsum of the Codroy Road Formation. The top of the type section, which occurs 100 m south of the cape, is bounded by a high angle fault which separates right-way-up beds from inverted Woody Cape beds farther south.

The outcrop of the formation is limited to the immediate area of Woody Cape and Capelin Cove. Inland, no outcrops have been found, although Hayes and Johnson (1938) made reference to some isolated exposures near Doyles and Upper Ferry. The rock types described, however, are equally common in younger and older formations and, in any case, they could not be located during the present study. Limestones possibly belonging to the formation were also described in a number of exposures along the Little Codroy River (Hayes and Johnson, 1938; Utting, 1966) but they were not visited by the writer.

Thickness

The type section as defined here is approximately 690 m thick.

General lithology

The Woody Cape Formation is predominantly a fine grained sequence of gray, gray-green, blue-gray and black mudstones, siltstone and shales. These are intercalated with green-gray, mica-rich sandstones, gray and black carbonates, and minor red siltstone and sandstone. The succession is characterized by its well bedded, sheet-like geometry (Plates 127, 128 and 130) in most all lithologies (see Figures 36 and 37on Foldout E). The mudstones and siltstones/sandstones (lithofacies D and E) comprise at least 60% of the formation and many parts of the succession are monotonous sequences of either structureless mudstone or regularly interbedded mudstone and siltstone.

Fossil- and carbonate-bearing marine shales (lithofacies A) form an important element of the lower 200 m of the formation but marine sequences of thin limestone, bioturbated mudstones and shales occur throughout the Woody Cape Formation. Evidence of subaerial environmental conditions is widespread in the upper 400 m of the formation. Redbeds are most common near the top of the type section. Lenticular channel sandstones (lithofacies F), although uncommon, are interspersed through the formation; they are thickest and most abundant in the middle part of the sequence.

A major coarsening-upward megasequence, 43 m thick (Section A, Figure 37) occurs in the basal 200 m of the type section. It consists of basal fossiliferous marine beds overlain by interbedded and graded mudstone and siltstone/sandstone (lithofacies D) and capped by sheet siltstones and sandstones (lithofacies E). For the first 20 m, the megasequence gradually coarsens upwards but the top is composed of several, thinner coarsening upward sequences, each 5 m thick, of the gray siliciclastics. Many other thinner coarsening and fining upward sequences, <5 m thick, occur throughout the formation.

Eight major lithofacies have been recognised within the Woody Cape Formation. They are A) shale lithofacies plus associated beds; B) massive silty mudstone lithofacies, C) laminated mudstone-siltstone lithofacies, D) interbedded mudstone and siltstone/sandstone lithofacies, E) sheet siltstone and sandstone lithofacies, F) thick sandstone lithofacies, G) red sandstone lithofacies and H) carbonate lithofacies.

(A) Shale lithofacies plus associated beds

Description of lithofacies A: Black and gray shales form sequences 3 to 34 m thick in at least three different associations. The first such association is black shale interbedded with dolomitic mudstones. The shales display well developed fissility and are interbedded with dolomitic, fossiliferous mudstone beds, 2-10 cm thick (Plate 125). The latter decrease in abundance upwards and are replaced by fossiliferous limestone concretions 5 cm thick. Fossils, which are generally less than 0.5 cm in size, include bivalves and brachiopods supplemented by plani- and high-spiral gastropods, straight orthocones, trilobite fragments and some possible branchiopods. Shales rich in ostracods, branchiopods and very small bivalves associated with nonfossiliferous shales lie stratigraphically above shales with a diverse marine fauna in Capelin Cove.

A second association lies above the first. It consists of gray shales interbedded at 20-40 cm intervals with 3-10 cm thick lumpy beds of sandy, micaceous and carbonaceous, coarse siltstone and silty mudstones. At the base, the lumpy beds exhibit fine bioturbation. Higher in the section however the siltstones are more evenly bedded and exhibit lamination, ripple cross-lamination and sharp, locally fluted and grooved bases. Here they form 150 cm thick sequences of 20 cm beds separated by a few centimetres of shale. They pass up into rocks of lithofacies D, the sequence as a whole having a upward coarsening aspect (Figure 37, Sections A and D).

The third association consists of interbedded, unfossiliferous shales and 2 to 20 cm, locally 120 cm, lumpy beds of black, unfossiliferous, massive or finely laminated, silty dolomite or limestone (Plate 126). The association occurs above thick channel sandstones (lithofacies F) at the northern point of Woody Cape and above fossiliferous black shales and dolomitic mudstones in Capelin Cove. Some fish scales, halite pseudomorphs and mudcracked surfaces occur locally. Stromatolites occur in some of the black dolomites as well as in yellowish weathering, sandy, dolomitic limestones. Small 2 to 4 cm stromatolite heads generally lack internal structure, but fine tapering fractures filled by white dolomite are common.

Interpretation of lithofacies A: The shale lithofacies was deposited subaqueously in a number of quiet environmental settings.

Quiet offshore marine deposition is suggested by the diverse marine fauna in the shales, calcareous mudstones, and limestone concretions as well as also by lumpy bedding and bioturbation in the associated siltstones of the first association. Sequences in which there is an upwards decrease of carbonate beds and bioturbation but an increase in frequency and thickness of current-deposited siltstones (Figure 37, Section A) are similiar to sequences produced when deltaic sand lobes prograde into an offshore setting (Elliott, 1976a, 1978).

Other sequences containing shales of the first association include one succession in which shales with a restricted dwarf fauna, including branchiopods, overlie shales with a diverse marine fauna. This suggests that the shales were first deposited in an open, fully marine bay which was later restricted, perhaps as distributary sands advanced into the bay or sand bars formed at the mouth of the bay. Consequently, the bay became brackish, as suggested by the restricted, dwarf fauna (Bell, 1929, 1948; Heckel, 1972).

The preservation of thin stromatolite beds, halite pseudomorphs and mudcracked horizons and lack of all fauna except some fish scales suggest that the shales and lumpy dolomite of the third association were deposited in low-lying interdistributary areas of the delta plain (Kanes, 1970). The stratigraphic position of these shales and lumpy dolomite, above channel sandstones and/or other shales interpreted as deposits of marine to brackish bays, suggests that they were deposited both adjacent to distributary channels and at the heads of bays. As such, they were probably deposited in shallow, frequently desiccated, lagoons, lakes and marshs provided with fine detritus by overbank flooding or marine storm flooding. Similar rock types, interpreted as delta-plain lake deposits, occur in Namurian deltaic strata from Northumberland, England (Leeder, 1974) and the Paleocene Difunta Group of northeastern Mexico (McBride et al., 1975).

(B) Massive silty mudstone lithofacies

Description of lithofacies B: This facies consists of deposits, 1 to 8 m thick, of blue-gray, green and red, structureless to thickly bedded (20 to 200 cm), hackly weathering mudstone. Although uncommon, this facies occurs in two sequences 20 m and 42 m thick in the type section and Capelin Cove section, respectively. In both places, they are intercalated with lithofacies C, D, E, and F. Upwards color changes from blue-gray and/or green to red are common within deposits.

Mudcracks, centimetre-size caliche nodules, and thin developments of wavy lamination or ripple and ripple-drift cross-lamination also occur in the mudstones where they are siltier and lie below lithofacies G red sandstones.

Laminae of yellowish weathering dolomite occur in a bedded red siltstone in strata south of and stratigraphically above the thick sandstone at Woody Cape.

Crystals, nodules, deformed lenticular layers, and crystal-lined vugs of strontianite ($SrCo_3$) (identified by Dr. Peter von Bitter, personal communication, 1978) occur in some structureless blue-gray mudstones. Finely laminated structure is disrupted by the strontianite in some beds.

Interpretation of lithofacies B: These thick, structureless mudstones are interpreted as floodplain deposits similar to those described for delta plains (McBride et al., 1975) and alluvial plains (Allen, 1965a). The thickness of structureless beds, some with thin units of ripple bedding or climbing ripple-drift, suggests crevasse flooding (Coleman, 1969) and rapid deposition of abundant mud and silt by ponded floodwaters. Drab to red coloration probably reflects water table changes. A high water table common to low areas of the delta plain promoted drab colors whereas build-up of the floodplain and lowering of the water table allowed oxidation and promoted the formation of red pigment in the fine muds (Friend, 1966; van Houten, 1973; McBride et al., 1975; Braunagel and Stanely, 1977; McPherson, 1980). Exposed surfaces were desiccated and small, pedogenic carbonate concretions formed in the muds. Strontianite probably formed early in the history of the mudstones, possibly diagenetically after celestite (Deer et al., 1974). The stratigraphic position of strontianite-bearing mudstone below fossil-bearing, marine shales suggests that the strontianite formed the mudflats that lay close to the marine environment.

(C) Laminated mudstone-siltstone lithofacies

Description of lithofacies C: Interlaminated green-gray, blue-gray and gray siltstones and mudstones comprise this lithofacies. They occur in 20 cm beds or sequences up to 4.5 m thick (Figure 37, Section F). The lamination is flat to microconvoluted, with some small discontinuities and scours filled locally by cross-lamination. Rare to abundant halite pseudomorphs and vugs, 1 - 5 mm in size, occur in some units and locally disrupt the lamination. No mudcracks were observed in the laminite itself but they were noted in one sequence on the bases of interbedded sandstone beds.

Interpretation of lithofacies C: Similar finely laminated mudstones in both the Codroy Road and Robinsons River Formations were interpreted as deposits of quiet water bodies fed by limited quantities of mud and silt. Mudstones of the Woody Cape Formation may have been deposited in shallow, sheltered, offshore settings such as bays (Elliott, 1974b, 1976b, 1978a; Wright, 1978) or shallow ponds or lagoon on the lower delta plain. Halite pseudomorphs suggest that some units were deposited in hypersaline ponds (Leeder, 1974). Mudcracks at the base of interbedded sandstones indicate that many pools on the delta plain were repeatedly desiccated and recharged by overbank flooding.

(D) Interbedded mudstone-siltstone/sandstone lithofacies

Description of lithofacies D: This facies consists of regularly interlayered blue-gray mudstones and gray-green siltstones, or, silty, very fine, micaceous and carbonaceous sandstones (Plates 127, 128). The lithologies occur generally in 30 to 150 cm beds that are either sharply interstratified or else fine or coarsen upwards. The facies forms sequences up to 5 m thick.

Most fining-upwards beds have sharp, planar to locally erosive bases, some carrying basal sole marks. These beds exhibit planar lamination overlain by ripple, or ripple-drift cross-lamination, or cross-lamination alone. Shale lenses are common in the cross-lamination. The coarse beds grade upwards into structureless mudstones which commonly have bioturbated tops where this facies occurs above marine shales. Sequences composed of fining upward beds in some instances coarsen upwards into lithofacies E lithologies which show evidence of emergence.

Coarsening-upwards beds (Plate 128) consist of massive basal mudstone which gradually becomes siltier and laminated and cross-laminated upwards. It then grades into a coarse cross-laminated, siltstone which has a sharp flat top (Plate 129). Convolution of lamination in the top of the mudstones is common.

Sharply interstratified beds consist of generally structureless mudstones and cross-laminated coarse beds. Mudcracks are common in these interstratified sequences. Most paleoflow directions of ripple-drift in the lithofacies are directed southwards but some beds near the top of coarsening-upward sequences flow indicators directed to the north.

Interpretation of lithofacies D: The interbedded mudstones and siltstones or silty sandstones of this lithofacies were deposited both subaqueously or subaerially. Bioturbation of tops of mudstone beds, lack of desiccation features in many sections, and stratigraphic position above marine shales support subaqueous deposition for some sections of the facies. Graded siltstone-mudstone beds with sharp locally fluted bases, internal structure consisting of lamination overlain by ripple lamination and then structureless mudstone resemble 'turbidite' deposits possibly laid down by decelerating density underflows.

The sheet-like graded beds overlie basal marine shales within thick coarsening-upwards sequences. As such, they are interpreted as deposits of deltas that prograded into an offshore basin (Kelling and George, 1971; Elliott, 1976a). Single beds that gradually coarsen upwards as well as thin coarsening-upward sequences of graded beds are interpreted as crevasse splay deposits. These formed in shallow interdistributary bays or delta plain lakes when floodwaters breached the main distributary channels and flooded adjacent interdistributary areas (Elliott, 1974b, 1975, 1976a; Horne et al., 1978). Where these crevasse deposits aggraded above water level, they were desiccated. The reversal of paleocurrent direction in the top bed of some sequences suggests that wave reworking occurred in some deposits after the splay was abandoned (Elliott, 1974a, 1974b, 1975, 1978a; McBride et al., 1975).

Other rocks of this facies were also deposited upon the delta plain. There, they formed sequences of regularly alternating siltstone and mudstone beds characterized by sharp contacts, no apparent trends, and some mudcracked horizons. These rocks suggest that the delta plain was built up by repetitive pulses of overbank flooding.

(E) Sheet siltstone-sandstone lithofacies

Description of lithofacies E: Sheet-like coarse siltstone and fine to very fine sandstone beds form an important element of the formation. They occur as single beds, 10 to 130 cm thick (Plate 127), and in sequences of several beds, several metres thick (Plate 130). The thick sequences either form the upper parts of coarsening-upward sequences completed by scour-based sandstone (lithofacies F) (Plate 127) or fine upward into overlying mudstones. The sandstones of this lithofacies are commonly rich in mica and comminuted fossil plant remains.

Sharp tops and bases characterize the sandstone beds in the facies. Internal structure is generally thin planar stratification and lamination with parting lineations and/or ripple cross-lamination. Ripple cross-lamination may repeatedly underlie planar lamination throughout a single bed. In other beds, cross-lamination is overlain by lamination, and then small crossbeds that contain mudclasts, the bed being completed by ripple cross-lamination. Convolution of internal structure is common.

Current direction of ripple bedding indicates a fairly consistent direction to the west and south in sheet sands of coarsening-upwards sequences.

Thick beds composed of either rib-and-furrow cross-lamination with shale drapes or climbing ripple-drift (Plate 127) occur above some coarsening-upward sequences (Figure 37, Section B). Ripple-drift of types A and B (Jopling and Walker, 1968) fill one such bed 127 cm thick. This bed has a slightly erosive base above which the consistent direction of the ripple-drift is 180° azimuth.

Overlying this 127 cm bed is a second coarsening-upwards sequence, 4.5 m thick, in which lithofacies D passes up into lithofacies E (Figure 37, Section B). Ripple cross-lamination is consistently directed southwards in this sequence but changes to 018° in a single sheet-sandstone bed, 40 to 76 cm thick, which caps the sequence. The higher sandstone bed has a sharp, flat to scoured base and undulose top. It is composed internally of ripple cross-lamination which locally passes into crossbedding.

Interpretation of lithofacies E: Thick sequences of sheeted current structured siltstones and sandstones of this lithofacies were deposited at the active front of prograding delta distributary channels. This is supported by their sheet-like geometry, sharp bases and tops, the predominance of ripple cross-lamination and planar lamination, unidirectional paleocurrent vectors and their association within coarsening-upward sequences. Sharp lithological contacts and shale drapes between beds suggest that each bed represents a distinct depositional event. The abundance of rib-and-furrow structure suggests that small linguoid or lunate ripple trains were characteristic of the sand beds (Harms, 1975). Where the sheet sands occur with lithofacies A and D, or C and D in decimetre-thick coarsening-upward mega-sequences, they are interpreted as fluvially dominated distributary mouth bar deposits (Elliott, 1976a) or crevasse-splay sand lobes that infilled shallow interdistributary bays or delta plain lakes (Elliott, 1974b). Reworking of the mouth bar by wave action may account for some reversal of paleoflow within the uppermost beds of some sequences.

Single sheet sands composed entirely of climbing ripple drift and lying within siltstones and mudstones (lithofacies D) probably formed as crevasse splays that were deposited in interdistributary areas of the delta flood plain.

(F) Thick sandstone lithofacies

Description of lithofacies F: Lithofacies F consists of medium to very fine grained, micaceous and feldspathic, green-gray sandstones in units 2 to 27 m thick. These rocks have channel-scoured bases with relief of several metres. Lenticular bedding, mudstone lenses and plugs, and intraformational conglomerates are common.

Towards the base of the formation, the sandstones are rarely more than 4 m thick. There, they lie erosively at the top of coarsening-upward sequences that also include lithofacies D and E (Figure 37, Section B). Other lithofacies F sandstones lie directly upon bedded, in cases mudcracked, mudstones and siltstones of lithofacies D and locally upon mudstones of lithofacies B. Two variations occur. The first consists generally of ungraded sandstones. They begin with a basal scour and mudclast lag which are overlain by planar stratification with parting lineations and in turn by flat bedding formed of ripple cross-lamination; channels up to 1 m deep filled by large, trough crossbeds downcut into the top of some units.

The second type, in contrast, begins with 20-70 cm lenticular, scour based beds of sandstone and mudstone that are in turn overlain by sandstones. Whereas the lenticular mudstones, apart from some coal lenses, are mostly structureless, the sandstone lenses display flat to undulose parallel lamination with parting lineations, cross-lamination and rib-and-furrow structures. Large scale trough crossbedding, ripple cross-lamination and some planar lamination characterize the sandstones above the lenticular deposits.

Thick multistory, fining-upward sandstones (Figure 37, Section C) form a third type of deposit which occurs higher in the formation. These consist of large scale trough crossbeds together with planar stratification and lamination. Lenses and layers of intraformational conglomerate composed of mudclasts and plant debris lie within troughs and along scours at the base of the members. Crossbeds dominate most deposits, and only towards the top of the sandstones does planar stratification with parting lineations and cross-lamination take over. These top beds may be at least 4 m thick. They are commonly rich in mica and fine plant fossil material and include rib-and-furrow structure (Harms, 1975) and climbing ripple-drift of types A and B (Jopling and Walker, 1968). Soft-sediment deformation is also common in the lithofacies and is locally truncated by scours.

Directions of ripple-drift, parting lineation, and some crossbeds suggest that current flow was consistently to the south.

Interpretation of lithofacies F: Basal scours, local channel geometry, intraformational conglomerates, trough crossbeds, planar stratification, and apparent unidirectional paleoflow suggest that these are deposits of river channels.

Where they scour into the tops of coarsening-upward sequences interpreted as distributary mouth bars, the sandstones were probably deposited in distributary channels that supplied a prograding delta lobe. Thicker, multistory, fining-upward deposits, however, more closely resemble sequences typical of meandering river channels (Allen, 1965a and b) and were probably deposited in principal distributary channels higher on the delta plain (McBride et al., 1975). Ripple cross-laminated, fine micaceous sandstones at the top of some deposits are perhaps levee deposits (Coleman and Gagliano, 1965) or fills of abandoned channels (Kelling and George, 1971; Gersib and McCabe, 1981).

Sequences which are associated with delta plain deposits (lithofacies B and D) and are composed of lenticular sandstones and mudstones overlain by trough crossbedded sandstone were probably deposited by small distributary channels in which the fluvial regime changed with time. Scour and fill structure, horizontal lamination in the lenticular sandstone, and variation of lithology suggest that the lenticular sandstones and mudstones were first laid down by low sinuosity, possibly ephemeral, streams (McBride et al., 1975). The change upward into crossbedded sandstones suggests these channels later became permanent distributaries possibly due to channel switching on the lower delta plain (Kanes, 1970; Donaldson et al., 1970).

(G) Red sandstone lithofacies

Description of lithofacies G: Interbedded within some red silty mudstones are beds of very fine, red sandstone up to 170 cm thick. They lie sharply within or upon the finer redbeds (lithofacies B). Internally, the red sandstones are composed of flat laminations and type A ripple drift (Jopling and Walker, 1968). The thickest sandstone of this type rests gradationally upon a bed 4 m thick of silty mudstone (lithofacies B). The latter begins with structureless mudstone and is completed by silty mudstones displaying climbing ripple-drift cross-lamination. The red sandstones in turn grade up into gray, laminated, coarse siltstones. Gray sandstones of similar structure also occur in gray silty mudstones within the succession.

Interpretation of lithofacies G: The structure and lithological association suggest that these beds formed by crevasse flooding upon the inner delta flood plain. The sharp but nonerosive base and flat stratification are similar to the Bijou Creek deposits (McKee et al., 1967). Climbing ripple-drift indicates rapid deposition of plentiful sandy sediment carried in suspension (McKee, 1965).

(H) Carbonate lithofacies

Description of lithofacies H: Carbonate beds composed of lumpy black dolomite and limestone or gray limestone concretions and beds have already been referred to during discussion of lithofacies A. Beds of gray, sandy limestone also occur in the upper part of the section (Figure 37, Section G) at Capelin Cove and above the thick sandstone unit at Woody Cape. These limestones range through lime mudstones to grainstones (Dunham, 1962).

Carbonate beds and concretions within the shale sequences near the base of the Woody Cape Formation vary from lime mudstones to wackestones. The beds are characterized by a system of tapering, irregular fissures that crosscut the depositional fabrics. The lime mudstones typically consist of carbonaceous and pyritic micrite with no fauna except a fine spicular structure, now preserved by clear microspar. Wackestones contain scattered to abundant skeletal grains (Plate 131) that include either all ostracods or a mixed skeletal component including crinoids, gastropods, foraminifera, and whole or fragmented brachiopods, bivalves and ostracods. Hollow-walled, and solid calcispheres are common. A tubular-walled structure similar to **Tubertina** (Mamet, 1970) occurred in one fissure.

Fissures, skeletal fragments and living chambers of organisms were lined by fine radiating calcite which was overlain by brown dusty, radiaxial fibrous mosaic cement (Bathurst, 1975). Most of the skeletal grains except crinoids were recrystallized to or replaced by blocky calcite; traces of original layered structure are visible in some recrystallized fragments. Remaining porosity within the fracture system was closed by coarse blocky calcite.

The grainstones at the top of the Capelin Cove section overlie 95 cm of laminated mudstones (lithofacies C) and a gray, wavy-bedded, argillaceous micrite bed 1.6 m thick. The grainstone consists of a lower calcirudite bed, 22 cm thick with an undulose erosive base, overlain by 43 cm of calcarenite. The calcirudite is composed of angular, irregular to platy mudstone, siltstone and limy intraclasts, 1 cm in size. The clasts are set in a sandy matrix cemented by clear calcite. The limy intraclasts include ostracod-rich and spicule-rich wackestones. Other wackstone intraclasts contain peloids and calcispheres. Silty and mottled lime mudstone intraclasts, dolomitized platy fragments suggesting derivation from laminated lime mudstones, cryptalgal laminite and grains composed of a radiating fibrous cement are also present. Many dolomitized intraclasts also occur. Some lime mudstone clasts have sand- and micrite-filled burrows. Skeletal allochems include abundant crinoids, some thick-walled bivalves with prismatic and cross-lamellar structure, foraminifera, brachiopod shells, whole or fragmented ostracods, and some scattered vertebrate fragments.

The overlying calcarenite is very coarse grained (Folk, 1962) and has thin, flat to wavy bedding, and small, westward directed trough crossbeds at the top. Crinoids and algal grains (Plate 132) similar to phylloid algae thalli (Horowitz and Potter, 1971; Bathurst, 1975) dominate the calcarenite. However, some foraminifera, including *Tetrataxis* and *Biseriammina windsorensis* (Mamet, 1970), and ooids also occur. Micritic envelopes outline skeletal and algal grains, many of which were subsequently dissolved to produce moldic porosity.

Fine calcite cements rim allochems and many sand grains and clear blocky calcite, 0.05 to 0.1 mm in size, cemented moldic and interparticle porosity. Syntaxial overgrowth of calcite occurred on some crinoid particles.

Interpretation of lithofacies H: Two environmental settings are described in this lithofacies.

The first includes limestone beds and nodules, some rich in fossils, that are part of a succession of shales previously interpreted as deposits of a quiet offshore setting. The presence of crinoid ossicles and the abundant shelly fauna in these limestones indicate that normal marine conditions prevailed.

The radial cements that rim and line skeletal grains and chambers are early marine cements (Shinn, 1969; Scholle, 1978; Longman, 1980). Similiar cements occur with *"Tubertina"* in fissures in the limy beds and concretions. This suggests that the fractures formed early, as the carbonates accumulated on the sea floor.

A high energy environment was more likely for the grainstones at the top of the Capelin Cove section. The spar-cemented calcarenite and calcirudite lie upon an erosion surface that may be part of a large channel.

Clasts derived from silty and burrowed lime mudstones, skeletal wackestones, stromatolites, and partly and completely dolomitized algal mat were mixed with ooids and with shell, crinoid and phylloid algal fragments. This diversity of clasts suggests a wide range of environments in which the original carbonates were deposited, including normal quiet marine lagoons and supratidal algal flats in which dolomitization had occurred. The preservation of many phylloid algal thalli and the angularity of clasts suggest, however, that the transport distance was small. Nevertheless, although the grainstones clearly indicate marine conditions, there is little additional evidence of marine influence in the succession with which the grainstones are associated.

Micritic envelopes around phylloid algae and skeletal grains and radiating fibrous cements (Shinn, 1969; Taylor and Illing, 1969) in some clasts suggest some early marine diagenesis and lithification before and after erosion. Dissolution of shell fragments occurred. Partial infill of algal thalli by fine mosaic spar, syntaxial overgrowth of crinoids fragments and closing of inter- and intra-particle porosity by clear blocky spar suggest that freshwater vadose and phreatic cementation affected the rudite deposits (Scholle, 1978; Longman, 1980) after their deposition.

Paleocurrents in the Woody Cape Formation

Because of the steeply inclined to overturned nature of the succession and lack of bedding plane exposures, paleocurrent direction could be measured accurately only on small scale, ripple cross-lamination and some parting lineations. The distribution of the cross-lamination is polymodal with a strong south-southeast vector which parallels the trend of parting lineations. Some crossbeds from thick, lithofacies F sandstones also gave a south-southeast direction. Nonetheless, some northward directed ripple-lamination and crossbeds occur above or at the top of coarsening upward sequences in beds directly above those with southward directed paleocurrents.

The extent to which directions have been reoriented by block faulting and deformation is not known but caution should be taken in interpretation.

Paleontology, age and correlation of the Woody Cape Formation

Several units of limestone and shale have yielded an abundant fauna in the Woody Cape Formation in Capelin Cove. Fossils are also reported from the type section by Hayes and Johnson (1938), Bell (1948) and, more recently, by McGlynn (personal communication, 1979). McGlynn identified several fossiliferous bands with a diverse brachiopod, bivalve and gastropod fauna (Table 9). Layers rich in small bivalves but lacking other fossils also occur in the fossiliferous shale sections. Ostracods and fish scales were noted in some carbonate beds.

The fauna is both marine and nonmarine. Bell (1948) describes a number of horizons with the branchiopods, Leaia and **Pseudotheria** which he suggested were nonmarine. Branchiopods can however also occur in brackish water (Heckel, 1972).

Limestones from the Woody Cape Formation recently yielded conodonts of the Gnathodus conodont zone (von Bitter and Plint-Geberl, 1982) including **Apatognathus**, **Mestognathus**, **Gnathodus girtizi**, **G. bilineatus**, **Hindeodus cristulus**, **Spathognathodus campbelli** and **Spathognathodus** n.sp.A.

Animal tracks believed to have been made by amphibians were briefly mentioned by Utting (1966) from some beds north of Woody Cape.

Miospores were recovered (Table 9) from samples collected at Capelin Cove (Utting, personal communication, 1978).

The macro- and microfaunas of the Woody Cape Formation have been correlated with those of subzone D and E of the Windsor Group (Hayes and Johnson, 1938; Bell, 1948; McGlynn, personal communication, 1978; von Bitter and Plint-Geberl, 1982). Hayes and Johnson (1938) originally gave a subzone D age for the basal beds of the formation and this is generally substantiated by recent study of shelly faunas. McGlynn (personal communications, 1978) correlated the fauna with subzone D and possibly lower subzone E and stated that they were similar to the faunas of the Avon, Meander River and Wallace Point limestones of Nova Scotia (Moore and Ryan, 1976). The conodont fauna also gives an upper Windsor age typical of subzone C to E in Nova

Scotia (von Bitter and Plint-Geberl, 1982). Miospore assemblages did not yield definitive forms to differentiate a lower or upper Windsor age (Utting, personal communications, 1978).

Depositional environment of the Woody Cape Formation

A deltaic environment for the Woody Cape Formation is indicated by: (1) the overall drab-colored strata (cf. Sutton et al., 1970; Walker and Harms, 1971; Flores, 1972; Mazzullo; 1973; McBride et al., 1975), (2) the paucity of redbeds, (3) the presence of marine strata at the base of and intermittently through the succession and (4) the importance of variable scale, coarsening upward sequences built up particularly of interbedded mudstones and sheeted siltstones and sandstones and, in some instances, marine shales (see also Bell, 1948). The importance of subaerial features, the scarcity of marine units and the presence of channel sandstones in the upper 400 m implies that much of the formation was deposited however in the subaerial portion of the deltas following an early phase of deposition that included both marine and nonmarine sedimentation (see Figure 35).

Elucidation of the depositional history of the formation is based on only two correlatable sections (Figure 36) which occur north and south of Woody Cape. Basal marine beds indicate a widespread, late Windsor marine incursion (Bell, 1948) flooded the southwest corner of the subbasin. Fossil and limestone-bearing shales were laid down over mudcracked and halite-bearing gray mudstones that were deposited upon the lower delta plain. A diverse fauna in the shales suggests near normal salinities and depths sufficient to allow quiet suspension sedimentation. This marine transgression probably reached as far north as the inner Codroy lowlands, where two marine sequences are intercalated in fine flood plain and playa-flat red siltstones and mudstones of the time-equivalent Mollichignick Member of the Robinsons River Formation.

The succession in the two sections of the formation diverge in character above the basal marine shales. Coarsening upward megasequences and sequences composed of sheet-like deposits of mudstones, siltstones and sandstones occur in the lower 200 m of the type section north of Woody Cape. They suggest active deltaic sedimentation gradually overwhelming the marine influence in the northern section. The delta front was built up by sheet-like deposits of graded silt/sand and mud deposited from mud and sand-laden density currents that spread out over the low-lying, open sea floor ahead of the distributary channel mouth. A delta platform was thus built up by processes that suggest a fluvially dominated delta (Galloway, 1975). Rapid aggradation of deposits up to and above sea level resulted in the formation of a delta plain. The thickest coarsening-upward megasequence consists of basal marine shales which pass up through delta front muds and sheet sands and are capped by mudcracked deposits. This megasequence which is 43 m thick suggests a maximum water depth of no greater than 40 m (Klein, 1974). Other upward-coarsening sequences however average 10 m thick. This thickness may be closer to the true depth of marine flooding, especially if one allows for compaction and basin subsidence.

No comparable coarsening upward sequences occur in the Capelin Cove section. Here, rather, the basal marine fossiliferous shales pass up into nonfossiliferous or sparsely fossiliferous shales with some coarsening upwards beds of mudstone and silt/sandstone. Overall the succession appears to document the gradual infill of a quiet interdistributary bay by mud and periodically by short-lived, sandy crevasse splays. Faunal changes upward in the shale section from a diverse marine to a small size, restricted fauna probably indicates that the bay was initially affected by the influence of open marine waters. With time however it became closed and brackish as it silted up or was closed off by delta or sand bar construction. In due time, muds of the shallow bays aggraded to and above sea level to become part of the delta plain. The evidence for the delta plain is present in the upper part of both sections through the Woody Cape Formation. Nevertheless, limited marine fossil-bearing beds suggest that a salt water influence did lie in close proximity to the delta plain in the upper part of the formation. The delta plain was crossed by distributary channels. These channels separated a variety of environments in the plain including a complex of shallow bays, brackish and freshwater lagoons, lakes, ponds and marshes (Horne et al., 1978). Immediately adjacent to channels, levees were developed and, higher on the delta plain, floodplain deposits were important.

In the complex of shallow bays, lakes and on parts of the outer delta plain, overbank flooding and crevassing from adjacent channels deposited laminated mudstone (lithofacies C) and coarsening upward sequences (Elliott, 1974b) of lithofacies D and E. The sequences compare to deposits of delta plain lakes in the Rhone delta (Oomkens, 1970) and to Tournaisian fluvio-deltaic strata of the Lower Border Group, Northern England (Leeder, 1974). The sheltered pools and lakes of the delta plain were, in some instances, gradually desiccated with salt crystals precipitated as the waters became hypersaline. Black shales with lumpy carbonates, thin stromatolites and some salt crystal beds were also deposited in shallow pools and marsh flats similar to those observed on modern and ancient deltas (Kanes, 1970; Leeder, 1974). Structureless mudstones as well as fining-upward sequences of sheet-sands and muds were laid down on the delta plain as floodwater overflowed channels and breached levees to form crevasse splays. Where the delta plain became elevated and drainage improved, oxidation of the mudstones and crevasse splay sands produced the minor redbeds of the formation.

Distributary channels that crossed the delta plain were probably of varying sizes depending upon their position on the delta. Multistory, fining-upward, channel sandstone deposits found in the upper half of the Woody Cape Formation suggest the presence of large, stable channels on the inner delta plain. The channels were flanked by prominent levees and were filled by thick, fine grained, micaceous, cross-laminated and convoluted sandstones when eventually abandoned. In sections below and between the thick multistory channel deposits, the channel sandstones are thinner and were locally subject to sporadic, ephemeral flow. A decrease in channel size may reflect subdivision of the main channel into several distributaries (McBride et al., 1975) by crevassing or avulsion on the delta plain.

Paleocurrent directions (although not plentiful and possibly reorientated by later deformation) appear to be dominantly to the south. Some northward directed paleocurrents, particularly at the top of coarsening-upward sequences, may reflect marine or lacustrine wave activity upon distributary mouth bar-sands after distributary channels were abandoned.

Petrography of the Codroy Group Siliciclastics

Thin sections of 60 siliciclastic rocks from the Codroy Group were examined and include very fine to very coarse grained sandstones, grits and some siltstones that were deposited in both fluvial and marine environments. The rocks are described in three sections. The first consists of siliciclastics of the Ship Cove and Codroy Road Formations which are very fine grained; the second includes sandstones of the Robinsons River Formation that are divided into those from the St. George's Bay lowlands, the Brow Pond lentil and the Codroy lowlands; lastly, sandstones of the Woody Cape Formation are briefly summarized.

The siliciclastics are mostly arkoses and subarkoses. They are generally immature to submature, composed mostly of angular to subrounded grains with variable amounts of matrix or cement. Siliciclastic rocks of the St. George's Bay lowlands are mostly carbonate-cemented, particularly those of marine affinity, whilst those of the Codroy lowlands commonly contain little carbonate cement.

Ship Cove and Codroy Road Formations

Several thin sections of gray, calcareous, coarse siltstones and very fine sandstones and sand laminae in laminated varicolored silty mudstones were examined in these two formations from both lowland areas.

The fine gray siliciclastics vary between well to poorly sorted (Beard and Weyl, 1973). They are composed mostly of quartz, micas, clays and some feldspar. Grains are mostly angular to subrounded, quartz overgrowths and sutured "contacts" obscure original grain boundaries.

Quartz is "common" quartz (Folk, 1968) with vacuoles and undulose extinction. Fresh grains of orthoclase, microcline and some plagioclase form less than 10% of the sediment. Flakes and shredded cleavage flakes of muscovite and chlorite are common; some green biotite occurs in the St. George's Bay lowlands but not in the Codroy lowlands.

Rock fragments, polycrystalline quartz and heavy minerals are virtually absent. Rare phyllite grains in halite-bearing gray siltstones occur in the Codroy lowlands. Zircon, tourmaline, rare garnet, magnetite, leucoxene and sphene were noted in sandstones of the Ship Cove Formation on Fischells Brook.

Kaolinite, illite, fine sericite and chlorite, patchy carbonate cement and pyrite and rhombic dolomite crystals form the matrices of the fine siliciclastics.

Robinsons River Formation

Lower Jeffreys Village Member

Sandstones below the Fischells limestone consist of poorly sorted to well sorted (Beard and Weyl, 1973), very fine to fine sandstones composed of angular to well rounded sand grains. Matrix is virtually absent and the sands were cemented by carbonate which etched grains; silica overgrowths of both quartz and K-feldspar grains are also common.

The sandstones are compositionally arkoses, typified by tabular to angular feldspars which include fresh microcline and fresh to altered microcline-perthite, perthite, plagioclase and orthoclase. Perthites include fine string and stringlet types as well as patchy replacement and interpenetrating types (Alling, 1938). Iron oxides cloud some orthoclases, and sericite and rarely epidote alteration had affected many plagioclase grains before erosion and deposition in the sandstones.

Muscovite, green biotite, and some felted chlorite grains are rare as are rock fragments. The latter, however, do include quartz-plagioclase plutonic grains, mafic volcanics composed of plagioclase microlites set in magnetite speckled chloritic matrix, and spherulitic and cherty silicic volcanic grains. Phyllites, quartz-muscovite schists and apparently undeformed siltstones are also present.

Quartz grains are mostly vacuole-bearing, 'common' quartz with slight to moderate undulose extinction. Composite quartz is rare; some quartz grains are both unstrained and clear with embayed boundaries suggesting volcanic quartz.

Zircon, tourmaline, garnet, epidote and magnetite compose the detrital heavy minerals.

Upper Jeffreys Village Member and Highlands Member

Very fine to fine grained red sandstones above the Fischells limestone of the Upper Jeffrey's Village Member generally show less variety than sandstones below the limestone although quartz, feldspars and phyllosilicates are the same. The red sandstones are, however, virtually devoid of lithic grains or detrital heavy minerals; only unaltered feldspars occur.

The detrital suite of coarse red sandstones collected from the Fischells Brook and Flat Bay area is, however, essentially the same as that of sandstones below the Fischells limestone. Feldspars are mostly unaltered although orthoclase may be cloudy due to disseminated iron oxides. Rod perthites and perthitic microclines are common. Volcanic and low grade metamorphic lithic fragments occur and include chloritic mafic volcanic grains, spherulitic and cherty felsic volcanic grains and quartz sericite and sericite-chlorite phyllites.

The quartz mode which includes some composite grains is mostly of "common" quartz of plutonic and vein origin; clear, unstrained quartz grains which retain prismatic crystal shapes and embayments typical of volcanic quartz phenocrysts also occur.

Some laminated sandstones associated with marine carbonates contain a diverse heavy mineral assemblage. This includes zircon, tourmaline, garnet, spinel(?), epidote, sphene, inclusion-rich staurolite and possibly red translucent rutile. Opaque grains include magnetite, leucoxene and a few grains of chromite.

Red sandstones of the Highlands Member type section although coarser grained and moderately well sorted, show little compositional variation from those of the Jeffrey's Village Member. Predominance of K-feldspar over plagioclase, the general lack of composite quartz and of volcanic and plutonic rock fragments but the continued presence of phyllites and quartz-sericite schists is characteristic. Antigorite rock fragments are also present.

Red sandstones examined from the St. Teresa drill hole and believed to have been deposited in a northeast trending trough, northwest of the Flat Bay anticline, contrast to the sandstones of the Highlands Member type section. They are typically poorly sorted and contain rock fragments, many of which are of plutonic and metamorphic origin. They include phyllites, quartz-muscovite, quartz-muscovite-epidote, and quartz-sericite-fibrolite schists. Grains of quartz and prismatic epidote of possible vein origin, and sheared and foliated plutonic rock fragments also occur. Grains of the latter include undeformed plagioclase porphyroclasts. Other plutonic rock fragments include quartz-microcline granites and unstained and iron-stained serpentinite grains.

Perthitic microclines, microclines, fresh and iron-rich orthoclase and plagioclase enclosing sericite and epidote alteration are common. Quartz grains include slightly to highly strained quartz and some stretched metamorphic quartz also occurs. Large flakes of muscovite and brown biotite and scattered splintery grains of epidote complete the detrital suite.

Brow Pond lentil

Fresh to altered feldspars, plutonic and some metamorphic rock fragments characterize the gritty and coarse grained arkosic sandstones of the Brow Pond lentil. The siliciclastics are mostly free of matrix and cements so that the rock is characterized by good interlocking grain contacts. Red to brown iron oxides coat grain boundaries.

The feldspathic mode of the arkoses consists of fresh microclines and perthites and cloudy iron-rich orthoclases. Plagioclase is fresh or contains variable amounts of sericite alteration. Plagioclase is particularly common in one thin section. Here the grains display coarse to fine albite twinning that allowed determination of an andesine composition for the feldspars. Perthites include string mesoperthites resembling those of Acadian granites of the Lloyds River intrusive suite (Kean, personal communication, 1981). Acid plutonic rock fragments include plagioclase - K-feldspar with myrmekitic quartz, microcline enclosing quartz and twinned plagioclase phenocrysts, quartz-microcline and quartz-plagioclase assemblages; plutonic rock fragments also enclose muscovite flakes. A possible tonalite grain composed of fresh Carlsbad twinned plagioclase and quartz was also noted.

Rock fragments derived from a low grade metamorphic terrain include phyllite, metasiltstones, and chlorite-sericite and quartz-chlorite schists. Phyllosilicates include muscovite, some green-brown biotite and chloritic biotite with strongly anomalous interference colors. Unicrystalline and composite "common" quartz is generally undeformed to slightly strained, typical of plutonic or vein origin.

Mollichignick and Overfall Brook Members

The sandstones of the upper members of the Robinsons River Formation, in the Codroy lowlands, include arkoses and subarkoses. Gray to red sandstones of the Mollichignick Member are frequently argillaceous and micaceous, containing up to 50% mica in some sandstones. The clay matrix which is composed of kaolinite, illite(?) and fine chlorite is mostly masked by iron oxide impregnation. Carbonate cements in intergranular voids are uncommon except in marine sandstones. The sandstones of the Overfall Brook Member are predominantly arkoses, with variable matrix, little cement and poor to well developed grain contacts. Sand grains are invariably angular in both members; some silica overgrowths occur.

Typical of sandstones in the Mollichignick Member is the abundance of strongly strained quartz grains compared to unstrained quartz. Composite quartz grains include stretched, schistose and equigranular recrystallized metamorphic quartz as well as "common" quartz of plutonic and vein origin. Much of the "common" quartz has been strained however and is locally recrystallized.

Feldspars are dominated by microcline and perthites but plagioclase and orthoclase also occur. The microcline which is rare in some sandstones of the Mollichignick Member is invariably fresh. Perthites include rod, stringlet, string, string mesoperthites, interpenetrating and patchy replacement types. Much of the orthoclase is turbid and some are rich in fine iron oxides. Plagioclases are unaltered, cloudy or partly sericitized and some contain myremykitic quartz. Granite rock fragments include quartz-plagioclase$\pm$muscovite, quartz-microcline$\pm$muscovite and K-feldspar-plagioclase assemblages in which graphic and myrmekitic textures are common.

Metamorphic rock fragments include phyllites and quartz-muscovite and chlorite schists and some quartz or quartz-sericite mylonites. Large mica flakes that consist mostly of muscovite, green biotite and felted and platy chlorite but include some brown to khaki biotites are distributed in the sandstones. Interlayered muscovites and green biotite occurs in some of the detrital flakes. Secondary iron enrichment and staining obscures many of the micas in the Mollichignick Member. Detrital heavy minerals include zircon, schorlite tourmalines, garnets, epidote, sphene and possible cassiterite. Hornblende was noted in the Overfall Brook Member.

Sandstones within the Mollichignick Member northeast of South

Branch are supplemented with detritus not seen in 12 thin sections examined from the Overfall Brook Member. In particular, the sandstones contain abundant zoisite, garnets rich in inclusions, grains of fibrolite-muscovite schist and large plagioclases in which there is much sericite and epidote alteration.

Woody Cape Formation

The subarkosic and less commonly arkosic sandstones of the Woody Cape Formation are compositionally very similar to the sandstones of the Mollichignick Member with which they are laterally equivalent. The sandstones are either argillaceous or calcareous, very fine to medium grained arenites composed mostly of angular to subrounded sand grains.

Briefly summarized, abundance of highly strained "common" quartz, of stretched and mylonitic metamorphic quartz, dominance of metamorphic rock fragments of low metamorphic grade, abundance of green biotites and muscovite and importance of fresh microclines and cloudy orthoclase feldspar is similar to the Mollichignick sandstones. Graphic intergrowth of quartz and feldspar was noted but no composite quartz of plutonic origin and plutonic rock fragments were observed presumably reflecting the generally fine grain size of the sandstone (Blatt and Christie, 1963; Connelly, 1965; Cleary and Connelly, 1971). Heavy minerals include only chips of the ultra-stable minerals zircon, tourmaline and rare garnet

Interpretation of the Petrography of the Codroy Group

The detrital components in sandstones of the Codroy Group point to a catchment area that lay mostly southeast of the Long Range fault. Local variation particularly in the north of the subbasin suggests that a source also lay to the northeast of the subbasin at least during the deposition of sandstones that make up the St. Teresa drill hole.

In the north of the subbasin, sandstones of the Jeffrey's Village Member indicate a source terrain chiefly composed of granites but also containing silicic and basic volcanic rocks as well as some low grade metasedimentary rocks. Granites and less significant granodiorites and tonalites supplied detritus to the Brow Pond lentil in the northeast corner of the subbasin. String mesoperthites compare well to those of granites belonging to the Lloyds River intrusive suite (Kean, personal communication, 1981), which lie directly east of the lentil. These Acadian intrusive rocks are spatially closely associated with silicic volcanics, which also provided some of the pebbles and lithic sand grains to the older members of the Robinsons River Formation in this area.

An abundance of highly strained quartz and rock fragments derived from sheared intrusive and metasedimentary rocks occur in the red sandstones of the St. Teresa drill hole. These components point to a provenance in an upland that was composed mostly of highly deformed, metamorphic rocks, likely the Fleur de Lys Supergroup. A highland ridge is thus postulated to occupy an area between the northeastern extension of the Long Range fault and the Humber Arm allochthon highlands. Remnants of these Fleur de Lys highlands are presently seen west of Grand Lake (Knapp et al., 1979).

In general, detritus in the upper Codroy Group succession of the Codroy lowlands in the south of the subbasin shows marked differences to the Codroy succession in the north around the St. George's lowlands. This is most noticeable in the amount of highly strained quartz, the abundance of green biotite, the presence of a wide variety of feldspars and the occurrence of distinctive metamorphic grains and detrital heavy minerals. A provenance for the Codroy Group in the Codroy lowlands is probably found in the rocks of the nearby Long Range Mountains.

Two distinct alluvial fan sequences occur respectively in the Mollichignick and Overfall Brook Members. The argillaceous, iron pigmented, pebbly sandstones of the Mollichignick Member northeast of South Branch contain dominantly metamorphic pebbles. These sandstones also contain abundant detrital zoisite, inclusion-rich garnets and grains of sillimanite-bearing schists. Clean arkoses of the Overfall Brook Member only 12 km to the southwest, however, are composed mostly of perthites, microclines and granitic rock fragments with metamorphic and mylonitic rock fragments. Pebbles include silicic volcanics.

The detritus in the Mollichignick fan probably came from rocks of a northwest trending shear zone that lies directly opposite the member in the Long Range mountains (Chorlton and Dingwell, 1981; Knight, in Chorlton and Knight, 1983). The shear zone is associated with schists bearing sillimanite, zoisite and inclusion-rich garnets.

The arkosic detritus of the Overfall Brook Member implies the erosion of a dominantly granitic terrain with some silicic volcanic rocks. Recent mapping of the Long Range Mountains (Chorlton and Dingwell, 1981; Brown, 1976), however, indicates that these rock types are not found immediately adjacent to the Long Range fault but some 10-15 km farther southeast. This source terrain supports the earlier conclusions drawn from sedimentary facies in the Robinsons River Formation that the basin-mountain contact in late Codroy times did not coincide with the Long Range fault at least in the area of the Codroy lowlands.

The close proximity of the Codroy Group fan sequences to their source rocks in both the Codroy and St. George's Bay lowlands precludes substantial lateral displacements during or since the deposition of the Robinsons River Formation.

Age and Correlative Deposits of the Codroy Group

The Codroy Group is Late Mississippian in age and is correlated with the Windsor Group of Nova Scotia (Hayes and Johnson, 1938; Bell, 1948; Baird and Cote, 1964) with which it has close stratigraphic and lithological similarities (Table 10).

Both shelly and coral faunas (Bell, 1929), conodonts (Globensky, 1967; Baxter and von Bitter, 1979) and miospores (Utting, 1978, 1980) suggest that the Windsor Group is equivalent to the middle to late

Visean of Europe. Mamet (1970) studying the foraminifera of the Carboniferous of the Maritimes suggested that the Windsor Group was deposited in the late Visean and earliest Namurian, a possibility also hinted at by Globensky (1967). Other workers, e.g. Benson (1974), suggested that middle and perhaps early Visean is represented by the thick basal evaporites of the Windsor Group. Neves and Belt (1970) using miospores indicate that the base of the overlying Canso Group in Nova Scotia is late Visean.

Paleogeography and Tectonic Setting of the Codroy Group

The geologic history of the Codroy Group records combined marine and nonmarine sedimentation in the subbasin. In its general history, it compares broadly to that of the Windsor Group in the Maritime provinces (see Table 10). The Codroy Group commenced with the establishment and maintenance of widespread marine transgression. This dominated depositional environments for at least the basal 1000 m of the group leading to the formation firstly of limestone, and then limestone, evaporites and marine siliciclastics within Windsor subzones A and B. Increasingly, however, nonmarine redbeds, gradually overwhelmed the shallow margins of the Windsor Sea (Bell, 1929, 1948) and formed the remaining 3000 to 3500 m of the group (upper subzone B to subzone E). Some marine incursions produced isolated marine units stratigraphically high in the Codroy Group suggesting that the marine environment was never far away. This is most obviously expressed by the Woody Cape Formation and Mollichignick Member in the southwest of the basin. The late Windsor marine incursions (subzone D and E) were quickly buried beneath renewed fluvial sedimentation that filled the subbasin.

The initial shallow marine transgression which lead to the widespread deposition of basal limestones of the Ship Cove Formation flooded the subbasin from south of the Port au Port ridge to Codroy, apparently overstepping the confines of the older Anguille subbasin. Although contacts appear generally conformable, regional Maritime and global stratigraphic evidence has suggested to Geldsetzer (1978) that a long-lived hiatus of several million years separated the Codroy-Windsor Groups from the underlying Anguille-Horton rocks. This is perhaps reflected in the marked lithification of the Anguille Group when compared to friable Codroy strata. There is, nevertheless, little physical evidence that a major disconformity developed at this contact in the Bay St. George subbasin and a gradational contact on Codroy Island provides support for a conformable, time stratigraphic sequence.

The marine flooding was apparently shallow and gentle, advancing from north to south. The strikingly consistent Ship Cove Formation was deposited mostly on a quiet, low-lying, intertidal algal flat. Its landward margin lay to the south, whilst algal mat flourished in shallow subtidal waters in the north. In the Fischells Brook area, a thicker marine sequence suggests marine conditions had already been established there before the sea transgressed southwards.

Evaporites became important as the marine environment continued during deposition of the Codroy Road Formation (subzones A and lower subzone B). Basin analysis has shown that an elongate arm of the sea became the site of dominantly fine siliciclastic deposition and that this seaway was established between what is now Ship Cove and Fischells Brook. It was flanked to the north by a long-lived evaporitic sabkha, whilst a low-lying, coastal alluvial plain occurred to the south. The plain was periodically inundated by the Windsor sea so that grey shales, siltstones, limestones and sulfates were intercalated with nonmarine redbeds. The limestones were locally rich in marine faunas and locally formed biohermal brachiopod and bryozoan build-ups. It seems that normal marine waters reached the subbasin and marine conditions were maintained for sufficient time to allow firstly biohermal construction by a mature fauna and later marine lithification. Thicker bioherms grew in maximum water depths of 10 - 35 m and rose above the sea floor as suggested by rapid lateral thinning. Gradually increasing hypersalinity killed the organic builders of the bioherms. It also led to the deposition of subaqueous gypsum in shallow marine and nonmarine lagoons, and displacive gypsum in the carbonate and siliciclastic sabkhas. Fine red beds prograded over the marine evaporites in the south as regression reached its maximum development. At present, it is not clear whether salt was precipitated within this initial phase of evaporite accumulation along with gypsum. The thickness and purity of the Fischells Brook deposit contrasts to the bedded, impure nature of the salts of the Robinsons River and St. Fintan's deposits. This suggests that the Fischells Brook deposit might have accumulated east of the Flat Bay "divide" partly or entirely at the same time that the Codroy Road sabkha evaporites were being laid down on the flanks of the high.

The overall environment of the rocks above the Codroy Road Formation became increasingly saline. Salt accumulated in several subsiding depressions (sinks) that were separated by positive divides or arches in the north of the subbasin. To the south, redbed sedimentation was possibly maintained, although gravity lows near St. Andrew's (Hooker Chemical Corporation, 1971) suggest that a salt basin also occurred in the extreme southeast of the subbasin. The sinks had restricted connections to an arm of the Windsor sea, itself the site of salt deposition in an area now under St. George's Bay. Surrounding the salinas (Figure 39a) lay evaporitic mudflats spotted with hypersaline pools and muddy to sandy alluvial fans. At least one major river discharged into the northeast end of the subbasin, feeding at different times one sink or another as its channel switched direction during severe floods. The once shallow salinas deepened as marine or river flooding occurred and bird's-foot deltas built out into the shallow seas. An unconformity within the Brow Pond lentil in the northeast of the subbasin possibly correlates with this period of salt deposition.

The marine depositional environment gradually returned to near normal salinities in the middle of the Jeffrey's Village Member allowing the deposition of several thin limestone units set between thick, red, sandy alluvial sequences (upper part of subzone B). The succession records a transition in the subbasin as nonmarine terrigenous rocks gradually asserted dominion. Transgression produced shallow seas which were filled by carbonates deposited in algal banks and flats, oolite shoals and beachs, open and restricted lagoons, and an open shelf environment. The seas hosted a diverse to restricted fauna. Marine transgression probably originated from the north or west and included both short- and long-lived events. Marine sequences shoaled upwards and regression followed; redbeds buried the margins of the sea. The regressive terrigenous rocks include fine to coarse red alluvium deposited in coastal playa flats, flood plains, and in ephemeral, braided and less commonly meandering river channels. Pebbly alluvial fans formed near basin margins. Paleoflow was dominantly westward and northwestward from a southeastern mountain source across a narrow alluvial plain to the shallow seas.

Above the Heatherton limestone, a thick sequence of fine red terrigenous sediments was deposited. Red siltstone and shaly siltstone were deposited on a distal alluvial plain and in coastal playa flats. The redbeds then coarsened gradually upwards suggesting uplift of the source areas. Fluvial depositional environments evolved from a distal flood plain supplied mostly by ephemeral streams and some geographically restricted meandering rivers (upper Jeffrey's Village Member) upwards into a flood plain drained by large meandering rivers flowing along the basin axis in the Highlands Member (uppermost subzone B into lower subzone C). Alluvial fans were still, however, important along the southeast margin of the subbasin during deposition of the Highlands Member.

Restricted and widespread shallow seas flooded the alluvial plain at two intervals near the top of the Jeffrey's Village Member and on two occasions in the Highlands Member. In the Jeffrey's Village Member, these marine bands were immediately overlain by coarse fluviatile sediments. Particularly active fluvial sedimentation occurred in a fault-bounded, northeasterly trending trough northwest of Flat Bay during Highlands Member time .

Nonmarine sedimentation was maintained for much of the remaining Codroy Group, (Windsor subzones C to E). Unfortunately the record is now found only in the Codroy area, close to the southeast margin of the basin. Marginal alluvial fans fringed by sandy and silty flood plains flanked lacustrine basins in the earliest stages of the deposition of the Mollichignick Member (Figure 35A).

A stable flood plain, however, developed in the middle of the member and coincided with renewed late advance of the Windsor Sea into the southwest of the subbasin (Figure 35B). Drab colored, offshore, delta front and dominantly delta plain siliciclastic deposits were laid down in the Woody Cape Formation in the southwest. Further north fine redbeds of laterally equivalent Mollichignick Member strata suggest that a low, flat-lying flood plain (Figure 40B) was flooded on three occasions by the late Windsor sea. Nonmarine conditions regained prominance as uplift of the source area produced an upward coarsening megasequence in the upper beds of the Mollichignick and the overlying Overfall Brook Members. Alluvial fans again actively prograded into the subbasin and coarse sandy detritus reached the flood plain in braided streams and by sheetwash.

Source of detritus supplied to the subbasin during the Codroy Group came from highlands that lay mostly to the southeast of the Long Range fault but also at intervals from the southern end of the Humber Arm allochthon highlands. Most streams were probably steep-gradient, short-headed types. Fine sandy, deltaic facies associated with the evaporitic sequences of the Jeffrey's Village Member and the basal Ship Cove Formation probably indicate that some larger perennial(?) rivers also existed in the northeast of the area. They possibly originated deeper within mountains of central Newfoundland and hence survived during the most arid period in the history of the subbasin.

Climate affecting the subbasin during the evolution of the Codroy Group was mostly semiarid becoming arid during deposition of the evaporites, particularly the salt. Mature and old age caliches in some nonmarine sequences, calcretes in marine carbonates, redbeds with iron pigment forming early after deposition (van Houten, 1973; McPherson, 1980) and the presence of minor evaporites in redbeds confirm that the climate remained semiarid for deposition of most of the group. Nonetheless, higher precipitation in mountain source areas is indicated by: (1) the presence of large perennial rivers and lakes, (2) the large quantities of terrigenous material deposited in the subbasin and (3) the high sedimentation rates for sections which have only minor caliche development. Lack of caliche together with well washed sands and braided stream structure in the youngest deposits of the Overfall Brook Member imply that the climate became increasingly humid near the end of Codroy history.

The tectonic setting of the subbasin during the Codroy Group influenced the deposition. The main axis of the subbasin during deposition of the lower Codroy Group appears to have shifted northwestward from the axial locus of the Anguille Group to now lay beneath St. George's Bay. This may be partly reflected by present day outcrop patterns. It is, however, supported by the available thickness data, facies distribution data and geophysical surveys. The Codroy depositional axis apparently coincided with a persistent northeast trending arm of the Windsor sea. Sediments at least 5000 m thick were laid down in this trough. Active northeast trending faults generally influenced the distribution of sediments. Positive areas separated this main basin from other smaller depositories during deposition of the Robinsons River Formation (Figure 33). An important trough lay east and southeast of the Flat Bay 'divide' in the lower Robinsons River Formation and probably also in the Codroy Road Formation.

The 2700+ m of upper Codroy strata in the Codroy Lowlands also suggests that a trough formed southeast of the 'Anguille Mountain high' during deposition of the Mollichignick Member.

The overall width of the active Bay St. George subbasin expanded from 30 km in the Anguille Group to at least 45 to 60 km in the Codroy Group. Its shape, however, was no longer a simple linear basin but had a complex configuration of highs and lows (Figure 33). Presence of much thicker successions in different areas of the subbasin and at separate stratigraphic intervals, e.g. saline sinks at base of the

Jeffrey's Village Member and the pebbly sandstone-filled trough northwest of Flat Bay in the Highlands Member, suggests that fault movements initiated subsidence in separate areas of the subbasin at different times.

The southeastern margin of the subbasin lay along or just southeast of the Long Range fault. Alluvial fans and lithoclasts derived from the metamorphic and crystalline rocks to the southeast testify that the fault was repeatedly active throughout the subbasin's history. In particular, pebbles of silicic volcanic rocks resembling Silurian-Devonian volcanic rocks of central Newfoundland are present in sedimentary rocks as far south as the Codroy Valley. This implies that the Topsails Igneous Complex, the Lloyds River intrusive suite and the Windsor Point Group formed part of the upland terrains adjacent to this part of the subbasin.

Allocyclical control governed by the regional tectonic setting was probably the main factor influencing both nonmarine and marine sedimentation. The coarsening upward basin-fill sequence in the upper Jeffrey's Village and Highlands Members and the many coarsening upward sequences and megasequences that formed the two basin-fill sequences of the Mollichignick and Overfall Brook Members confirm uplift of source areas as a decisive factor in sedimentation. Nevertheless, fining-upward megasequences also occur and thick intervals of fine distal alluvium suggest long periods of basin stability when source areas presumably receded. Uplift may also have affected the climate of the source areas allowing greater precipitation. In general, uplift was followed by renewed generation and progradation of coarse alluvium into the subbasin.

Repeated cyclicity of marine and nonmarine beds in the Codroy Road Formation and in the middle part of the Jeffrey's Village Member also suggest an allocyclic, probable tectonic control for the repeated transgressive-regressive stratigraphy of much of the group. In particular, regressive coarse, pebbly sandstones deposited by braided streams were laid down above transgressive marine units in the Jeffrey's Village Member. This suggests basin subsidence coincided with uplift of adjacent source areas and gave rise to transgression. Subsidence was probably also the most important factor that allowed flooding of saline sinks during deposition of the lower Jeffreys Village Member. The arid climate of that period, however, perhaps counteracted the effect of uplift around the basin preventing influx of large quantities of detritus.

The broad similarity of the Windsor Group of Nova Scotia and the Codroy Group of Newfoundland implies that the tectonic control of sedimentation in the Bay St. George subbasin relates to a regionally active phenomenon. For example, Geldsetzer (1978, 1979) has suggested that the transgressions which flooded the Maritimes Basin reflect an overall setting below global sea level during the Visean. However, geological events occurring elsewhere within the global Hercynian system may have been a significant factor controlling the cyclical aspect of the succession. For example, several major transgressions are known to have affected northern Europe at this time (Ramsbottom, 1979). Eustatic sea level rise may have been an additional control of cyclicity in the Maritimes Basin. Such sea level changes respond to variations in volume of land ice, ocean basin capacity, growth of oceanic ridges, sediment accumulation or dessication of isolated basins (Pittman, 1978; Donovan and Jones, 1979).

The Windsor Group dominated by evaporites is generally assumed to underlie much of the center of the Maritimes Basin (Geldsetzer, 1979; Howie, 1979; Howie and Barss, 1975 a and b) but at present little is known about the full suite of rock types and facies there. It is difficult to assess how the Windsor Sea in the Maritimes Basin influenced marginal subbasins, such as the Bay St. George subbasin. For instance, Geldsetzer (1978, 1979) envisaged a large, generally land-locked basin drowned by marine flooding to a depth of hundreds of metres to explain the evaporite sequence in the Maritimes Basin. He did recognize, however, that the onland subbasins were probably shallower and influenced more by their marginal setting. This is certainly true of the Bay St. George subbasin where evaporites and associated siliciclastic facies are clearly of shallow, near-shore to shoreline origin . Fossil-bearing carbonates and bioherms associated with sulfate evaporites and redbeds in the Codroy Road Formation and shallow water to subaerial facies associated with salt sequences in the lower Jeffrey's Village Member oppose a deep basin origin for the evaporites of the Codroy Group as a whole.

Marine flooding from two distinctly separate sources each with its own salinity may in part account for the alternating normal to hypersaline character of the marine strata in the group. Normal seawater possibly entered the subbasin from a Variscan ocean that lay east of Newfoundland (Jansa et al., 1978; Jansa and Mamet, 1979) along a seaway which is postulated here to have formed around the tip and along the west side of the Great Northern Peninsula. This northern sea way is suggested by facies and faunal distribution in the Ship Cove and Codroy Road Formations and carbonate units of the Jeffrey's Village Member. It is also supported by the Carboniferous limestones of the Port au Port Peninsula which were laid down close to a shoreline after southward transgression of seawater into a paleo- Port au Port bay (McArthur and Knight, 1974). The transgression flooded into the Bay St. George subbasin around the western tip of the Port au Port ridge. This northern passage helps account for the near normal marine faunas of carbonates and biohermal buildups at the base of the cycles in the Codroy Road Formation. Formation of tidal flat to shallow lagoonal gypsum then accumulated in response to local conditions as regression occurred with the cycles completed by red-beds (cf. Schenk, 1969).

The salt-precipitating phase of the Codroy Group that followed quickly after the Codroy Road sulfate phase may be explained by temporary cut-off of the northern seaway. Saline waters from the Maritimes Basin were then fed from the west along the axis of the subbasin. This spilled over into the sinks where salts were readily precipitated with bittern salts accumulating as the phase continued.

The northern seaway was reopened again in the middle part of the deposition of the Jeffrey's Village Member. The marine waters, fed around the western tip of the Port au Port ridge, flooded the axial zone of the subbasin spilling over into the last vestiges of the saline sinks moderating their salinity. Each succeeding transgression rapidly but quietly advanced over a generally low-lying alluvial plain formed of the associated redbeds.

The final marine event of the Codroy Group involved the Woody Cape Formation and some beds of the Mollichignick Member (subzone D and E). The Windsor sea then flooded only the southwest of the subbasin, presumably from the south.

Clearly then, at least two oceanic connections may have existed in the history of the Windsor sea. Previously, most workers have favoured a seaway to the south of Newfoundland and across Cape Breton (Bell, 1929; Mamet, 1970; Geldsetzer, 1978), although Moore (1967) and Schenk (1969) showed that transgressions advanced into the Minas and Antigonish - Mabou subbasins of Nova Scotia from the north, i.e. from the Maritimes Basin. Although this newly postulated northern seaway had an important influence in the Bay St. George subbasin, the similiarity of stratigraphy (Table 10) between Newfoundland and Nova Scotia suggest that the subbasin was not isolated from the rest of the Maritime area.

Preliminary provenance studies of the various rock units of the Codroy Group suggest that there has been little or no relative lateral displacement of the source terrains and the subbasin. This is most clearly shown in the Codroy lowlands by the distinct detrital suites in the Mollichignick and Overfall Brook alluvial fan sequences of late Codroy age. Sandstones in the north of the subbasin that compose the older members of the Robinsons River Formation also indicate that source mountains lay in geologic terrains that presently surround the north of the subbasin.

Wrench movements have been postulated to control sedimentation during the Anguille Group when the basin appears to have evolved as a pull-apart structure. The broadening of the basin width during the Codroy Group, however, suggests simple pull-apart had ceased by the time lower Codroy Group strata was deposited. Many faults that were active wrenches during the deposition of the Anguille Group became inactive and were buried beneath the Codroy cover. This happened to the Snakes Bight fault and the fault that formed the northwestern and northern margins of the Anguille pull-apart basin. The irregular arrangement of actively subsiding troughs and uplifting archs suggest that wrench movements, however, continued into the earliest depositional phases of the Codroy Group. The fault that formed the northwestern margin of the Anguille pull-apart basin is believed to have straightened and extended northeastward toward the northwest margin of the Steel Mountain anorthosite during the deposition of the Codroy Group. This is supported by troughs filled by thick successions of Codroy strata including evaporites beneath St. George's Bay and northwest of Steel Mountain. The trough beneath St. George's Bay developed south of the southern margin of the Humber Arm allochthon highlands and suggests that the highlands must have shifted northeastwards by the earliest stages of the Codroy Group (i.e. late

Tournaisian or early Visean).

The thick sedimentary sequence of Codroy strata north of the Anguille Mountains accumulated in a basin that subsided rapidly after completion of the second pulse of Anguille Group basin pull-apart and infill (Table 3). The thin succession of late Anguille strata postulated to occur beneath the Codroy beds in this area means that basin extension continued after the Anguille pulses of basin pull-apart eased. Rapid subsidence followed during the deposition of the Lower Codroy Group, which aided in producing the notably thick 2000+ M section found in the north of the subbasin.

The detrital component of the rocks in the Codroy Group, particularly those close to the Long Range fault, suggest that lateral movements on the Long Range fault had stopped by Windsor subzones C to E. Instead vertical uplift occurred upon the fault. Block faulting probably dominated in the subbasin at this time along northeast trending, high angle faults. For example, the steep faults bordering the Indian Head Complex and the Steel Mountain anorthosite were displaced northwest side downwards. Thick Codroy sequences close to the faults together with unconformable relationships on the northwest side of the troughs suggest that the faults produced half grabens. The narrow trough of Mollichignick and Overfall Brook strata in the Codroy lowlands may also have occupied a half graben.

In the Deer Lake Basin fluvial and lacustrine sediments infilled a basin that widened northwestward outside the confines of a narrow, faulted depository full of Anguille strata. Here uplift of older terrains also occurred, (Figure 16) as did the thickening of Codroy-equivalent strata into and away from an unconformity along the northwest margin of the basin. It seems that the Visean syn-sedimentary tectonic framework of the Deer Lake and Bay St. George subbasins are comparable. An extremely thick sequence of basal Deer Lake Group strata near Glide Mountain suggested to Hyde (personal communication, 1982) that some basin pull-apart occurred early in the depositional history of this Windsor equivalent group. The timing of this event matches that postulated for the Codroy Group (Table 3).

CHAPTER 3

SUMMARY AND CONCLUSIONS

The Bay St. George subbasin is a Devonian-Carboniferous, dominantly nonmarine successor basin the formation of which was controlled by movements upon several northeasterly trending faults of the Hercynian Cabot Fault system. Sedimentation spanned a time interval of perhaps 45 to 60 million years starting in Late Devonian (Famennian) and continuing through to Middle Pennsylvanian time (Westphalian C). The basinfill includes the Anguille Group composed of lacustrine, fluvial-deltaic and fluviatile strata overlain by the Codroy Group dominated by fluviatile redbeds but including marine siliciclastics, carbonates and evaporites. Fluvial and coal-bearing strata of the Barachois Group were the last Carboniferous sediments to accumulate in the subbasin (Knight, 1983).

The important conclusions are outlined below.

Creation and Early Evolution of the Bay St George Subbasin

The Bay St. George subbasin began as a 'pull-apart' basin (Crowell, 1974a and b) controlled by right-lateral strike-slip faulting on the northeasterly trending Long Range and associated faults. The subbasin probably formed where a bend or more probably a splay fault developed off the Long Range fault southwest of the Steel Mountain anorthosite. The splay fault trended almost due west along the northern edge of the subbasin and then turned southwestwards to form its northwestern margin. The southwestern margin probably coincided with a north trending basement arch (Howie and Barss, 1975a) that lies offshore from Cape Anguille. The Long Range fault formed the southeastern margin of the subbasin for most of its geologic history. Basin pull-apart began probably as early as late Middle or early Late Devonian time and continued at least until early or middle Visean time. During this time interval, the basin extended southwestwards a distance of approximately 130 km.

Structural evolution of the subbasin during the deposition of the Anguille Group and basal Codroy Groups: During the deposition of the Anguille Group, the subbasin was a narrow northeasterly trending graben, 30 km wide, lying between uplands located to the northwest (the Humber Arm Allochthon highlands), the northeast (above and northeast of the Steel Mountain anorthosite), and the southeast (the paleo-Long Range highlands). This narrow subbasin was primarily influenced by its border faults, but faults such as the Snakes Bight fault within the subbasin were also active. Three thick basin-fill sequences occur. The first of Famennian age (Kennels Brook Formation) and the second of Tournaisian (to early Visean ?) age (Snakes Bight through Spout Falls Formations) make up the Anguille Group. The third is of middle Visean age and comprises the basal Codroy Group. These three sequences are arranged geographically within the subbasin from southwest to northeast respectively, suggesting that the locus of subsidence and sedimentation shifted northeastward as the pull-apart basin evolved.

During this basin extension, most detritus was derived from mountains situated northeast and southeast of the subbasin. The provenance areas are recognized as probably similar to those of the Lower Paleozoic metamorphic and volcanic-plutonic terranes that now lie northeast of the subbasin and east of the Long Range fault in central Newfoundland. To the northwest, the Humber Arm Allochthon highlands appear to have first provided detritus to the subbasin in early Tournaisian time during the deposition of the younger formations of the Anguille Group.

Distribution and relative ages of conglomerates in the Anguille Group that were derived from the Humber Arm Allochthon highlands suggest that the highlands originally lay 95 to 130 km southwest of their present position. They were displaced northeastwards during the deposition of the Anguille Group and occupied their present geographic position during the early history of the Codroy Group. Movement possibly averaged between 0.5 to 0.8 cm per year. During deposition of upper Anguille - basal Codroy rocks, the highlands may have been displaced as much as 60 km in as few as 5 million years, giving average annual displacements of 1.2 cm.

During the deposition of the basal Codroy Group, irregular distribution of small subsiding, evaporite-bearing troughs and of positive arches is believed to reflect the response of the subbasin to the last phases of active wrench movements.

Structural evolution of the subbasin during the deposition of the rest of the Codroy Group: There is no direct evidence for wrench fault movements during deposition of rocks younger in age than those of the basal Codroy Group. The stratigraphic record of the time interval represented by post-basal-Codroy Group and also by the overlying Barachois Group strata (Knight, 1983) indicates that the subbasin broadened to include the region now beneath St. George's Bay, a width of between 45 and 60 km. Beneath the bay, a 5-6 km thick sequence of Codroy and Barachois Group sedimentary rocks suggests this part of the subbasin became a major sediment depository as basement probably subsided in the area. Subsidence occurred principally along northeasterly trending faults that underlie the bay (Spector, 1969; Golden Eagle Developments, 1975).

Detritus in alluvium of the Codroy Group and later Barachois Group (Knight, 1983) suggests that the source lay principally in pre-Carboniferous terranes directly southeast of the Long Range fault in the paleo-Long Range highlands. Pebble distribution in the group indicates that Silurian-Devonian intrusive and volcanic rocks of central Newfoundland had a greater geographic distribution to the southwest than they do at present. Minor detritus was shed from the Humber Arm allochthon highlands locally into the northern end of the subbasin during the deposition of the Codroy Group. Some detritus was also derived from uplands composed principally of Fleur de Lys type metamorphic rocks that lay to the northeast of the subbasin. In the Codroy lowlands, upper Codroy Group sedimentary rocks are 4 km thick adjacent to the Long Range fault, which suggests that the subbasin was influenced by block faulting and the vertical uplift of the paleo-Long Range highlands. This uplift continued throughout the interval represented by the Barachois Group (Knight, 1983).

History of Sedimentation

Anguille Group: Sedimentation in the Anguille Group can be divided into two phases. The early phase consisted of redbeds of the Kennels Brook Formation that were deposited probably during Late Devonian time. These redbeds may have been part of a broad molasse blanket that had existed from Early Devonian time. Most likely, however, they represent the first deposits to accumulate in the pull-apart basin.

The second phase of sedimentation is of Early Carboniferous age (Hortonian). This phase records the formation and infill within the subbasin of a relatively deep, meromictic or oligomictic lake that formed under semiarid climatic conditions. Lake-bottom muds, lacustrine turbidites and large sandy deltas possibly associated with sublacustrine fans filled the lake (Snakes Bight Formation). As the lake was filled, it became shallow and was restricted to the southwest end of the subbasin, and delta, fan-delta, shallow lake shore environments and an extensive delta plain developed (Friars Cove Formation). The rocks of this formation change northwards and upwards into sandy redbeds of dominantly ephemeral and braided stream origin (Spout Falls Formation). The Fischells conglomerate member of the Spout Falls Formation was deposited locally in the northern part of the subbasin as coarse gravel fans near the end of this phase of Anguille Group sedimentation.

Codroy Group: Sedimentation in the Codroy Group began with marine transgression and deposition of limestones of the Ship Cove Formation. The marked change from nonmarine redbeds to marine carbonates at this contact suggests that a hiatus separates the Anguille and Codroy Groups. However, field relationships at the contact are ambiguous and paleontological information lacking so that the hiatus cannot be confirmed. Deposition of the Ship Cove Formation was followed by accumulation of marine carbonates and evaporites and of marine and nonmarine siliciclastic rocks of the Codroy Road Formation and the lower part of the Robinsons River Formation (Windsor subzone A and lower part of subzone B). Nonmarine sedimentation then gradually gained in importance upwards through the group as the upper part of the Robinsons River Formation and the Woody Cape Formation (upper subzone B to subzone E of the Windsor Group) were deposited.

The limestones and shales of the Ship Cove Formation were deposited on a quiet, intertidal, algal flat that extended northward into a subtidal setting. The landward margin lay to the southeast. The Codroy Road Formation formed in and near an elongate arm of the Windsor Sea located in the vicinity of St. George's Bay. The subbasin was flooded by near normal marine waters which yielded fossiliferous limestones and biohermal buildups. Shoaling caused evaporitic conditions to develop as regression proceeded. For example, gypsum was deposited widely in a stable sabkha flat in the north and in shallow lagoons and associated sabkhas in the south. Fine redbeds encroached northwards across a coastal plain in the southeast of the subbasin. Cyclicity of lithofacies suggests a number of transgressive - regressive cycles occurred. No evidence of deep basinal evaporitic conditions has been observed. Salt may have accumulated east of the Flat Bay 'divide' during deposition of the Codroy Road Formation.

The Robinsons River Formation is subdivided into four members and one informally named unit, the Brow Pond lentil. The members comprise a large variety of nonmarine and marine lithofacies. The Jeffreys Village Member consists of two sequences divided at the Fischells limestone. The lower sequence (lower subzone B of the Windsor Group) includes fine siliciclastics and some of the major salt deposits of the subbasin, which are postulated to have accumulated in several rapidly subsiding sinks. The salinas were shallow and surrounded by evaporitic mudflats spotted with muddy hypersaline ponds and fine muddy alluvial fans. Periodically, the salinas were flooded by freshwater and at such times rivers deposited deltas of fine sand into the salinas.

The upper sequence of the Jeffrey's Village Member probably formed a sedimentary blanket of more uniform thickness that consists of redbeds, marine carbonates and minor evaporites. Nonmarine environments in the redbeds of the upper part of the Jeffreys Village Member included playa flats, alluvial flood plains, ephemeral, braided and meandering streams, and coarse and muddy alluvial fans. Towards the top of the member, it includes a major coarsening-upward sequence that culminated in the deposition of the overlying Highlands Member (upper part of Windsor subzone B and Windsor subzone C). The redbeds of the Highlands Member were deposited by high-sinuosity rivers that flowed west-southwestwards along the axis of the subbasin.

Clean arkosic sandstones of the Brow Pond lentil were deposited as a major alluvial fan that built out into the northeastern corner of the subbasin. Other alluvial fans were present in the northern and along the southeastern side of the subbasin during the deposition of the upper Jeffrey's Village Member and the Highlands Member.

The marine deposits of the upper Jeffrey's Village Member occur mostly towards the base of the sequence. They include carbonates with some evaporites and siliciclastics that were deposited in shallow lagoons, algal banks and flats, oolitic and sandy shoals and beaches, and shallow shelf environments. The character of the carbonate units changes upwards within the Jeffrey's Village Member so that units displaying characteristics of open-marine shelf are superseded by those dominated by algal banks, oolite shoals and, rarely, lagoonal sulfate evaporites. Transgressions were slow and widespread, and both short- and long-lived marine conditions occurred. Marine sequences consist of shoaling-upward cycles and many of the marine carbonates developed calcretes and other features of vadose freshwater diagenesis. Dolomitization occurred in some units. The cyclic carbonate-redbed sequences of the member are typical of transgression and offlap sequences of the Windsor Group (Schenk, 1969).

Seawater entered the subbasin from the north and southwest during the deposition of the marine beds of the basal Codroy Group. The Variscan Ocean, east of Newfoundland (Jansa **et al.**, 1978; Jansa and Mamet, 1979) is suggested here to have been connected to the subbasin by a seaway that likely lay along the western side of the Great Northern Peninsula. Near-normal ocean waters flooded the subbasin along this seaway. When the seaway was cut off, hypersaline waters spilled into the subbasin from the larger Maritimes Basin, thus leading to salt deposition.

The Mollichignick Member (Windsor subzone D and E?) consists of two basin-fill sequences. The first is made up of lacustrine rocks, sheetflood-dominated alluvium and muddy, pebbly, semiarid alluvial fan deposits that are arranged in several coarsening-upwards mega-sequences. The second consists of playa flat and flood plain and meandering river channel deposits overlain by coarser braided stream deposits. These facies were capped by a humid alluvial fan sequence, the Overfall Brook Member.

The Windsor Sea flooded the southwestern part of the subbasin late in the depositional history of the Codroy Group (Windsor subzones D and E). Thin fluvially dominated deltas were deposited in the Woody Cape Formation. Delta lithofacies include offshore mudstones and siltstones, delta front sheet sandstones, delta channel sandstones and several lithofacies typical of delta plain subenvironments. The Windsor Sea also inundated the flood plain of the middle Mollichignick Member on several occasions.

During deposition of the Codroy Group, the subbasin was fed dominantly by short-headed, steep-gradient streams. However, evidence from the lower Codroy Group, especially in the salt-bearing strata of the Jeffrey's Village Member, strongly suggests that larger perennial rivers entered the subbasin in the northeast. Such rivers probably originated far within central Newfoundland.

Two paleoflow regimes occurred in the subbasin during deposition of the Codroy Group, and included northwestward paleoflow from basin margin towards basin axis and southwestward paleoflow along the axis of the subbasin. Arrangement of sedimentary depositional environments from the margin to the axis of the subbasin in relation to the northwestward paleoflow included (a) alluvial fan to sheetflood and sandy braided stream to lake environments, (b) alluvial fan to braided stream - ephemeral stream to distal flood plain or playa flat to marine environments and (c) alluvial fan to playa flat to marine environments. Lithofacies order associated with axial paleoflow was mostly from alluvial fan to braided or low sinuosity streams to high sinuosity streams to marine.

Climate during deposition of the Codroy Group was generally semi-arid. More arid conditions during deposition of the lower Codroy Group led to widespread precipitation of evaporites when influx of fine terrigenous material was low. Caliche, locally well developed at specific stratigraphic intervals such as the middle of the Jeffreys Village Member, the middle of the Highlands Member and the middle of the Mollichignick Member, support continuing semiarid climatic conditions for much of the time represented by the Codroy Group. Increased precipitation is suggested by the absence of mature and old age caliches in the youngest strata of the Codroy Group and by humid alluvial fan deposits of the Overfall Brook Member.

Variable calcrete (caliche) development suggests that sedimentation rates and tectonic stability in the subbasin varied greatly during deposition of the Codroy Group. Coarsening-upward megasequences and basin-fill sequences in nonmarine strata and cyclicity of marine and nonmarine beds also suggest tectonically controlled sedimentation. This tectonic activity was sited primarily upon the border faults of the subbasin, producing basin subsidence and source uplift which continued during the deposition of the overlying Barachois Group (Knight, 1983).

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STRATIGRAPHY, SEDIMENTOLOGY AND PALEOGEOGRAPHY OF MISSISSIPPIAN STRATA OF THE BAY ST. GEORGE SUBBASIN, WESTERN NEWFOUNDLAND

PART 2

IAN KNIGHT

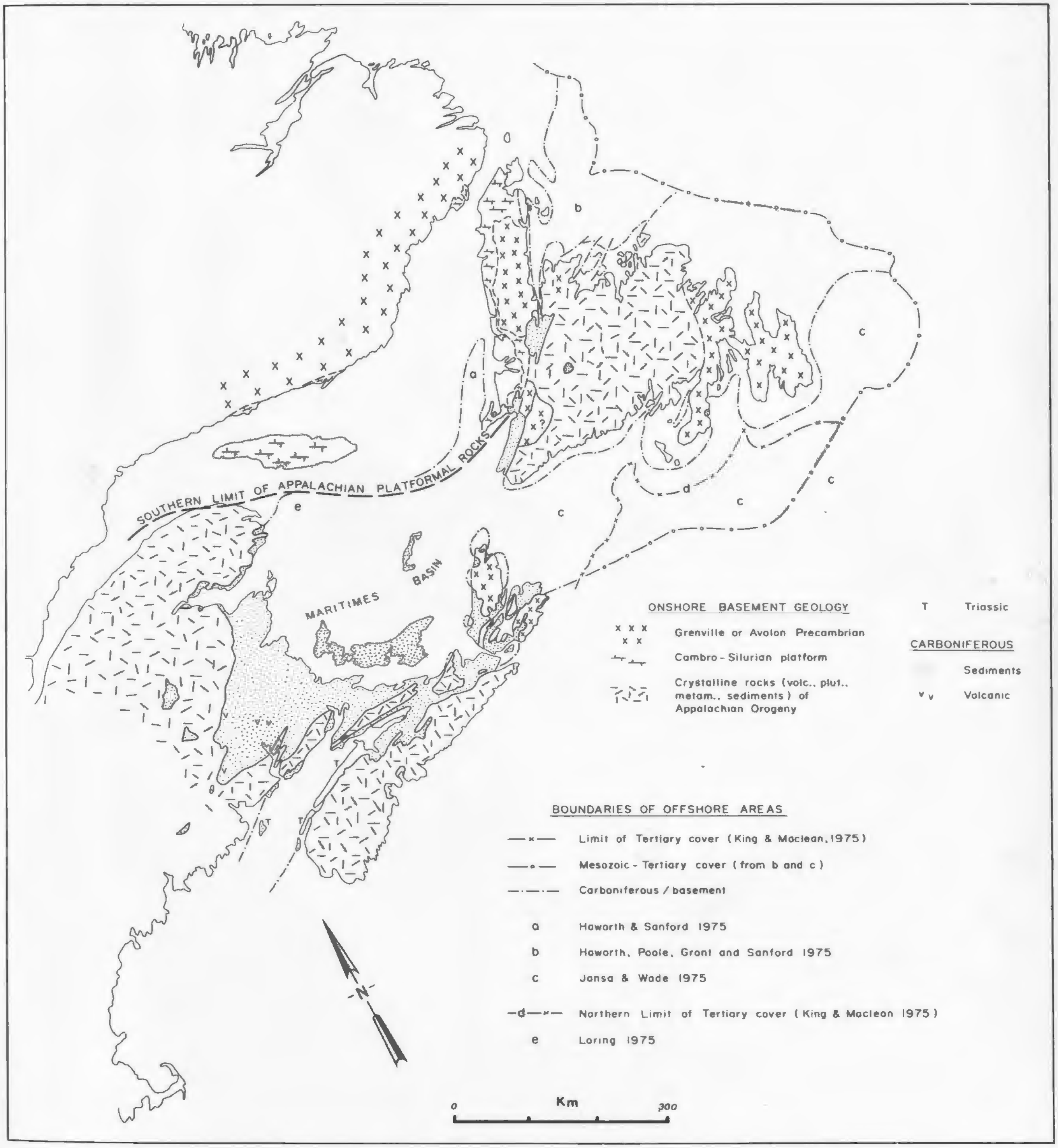


Figure 1: Generalized distribution of onshore Carboniferous strata and surrounding basement rocks in Newfoundland and the Maritime Provinces. Carboniferous-basement relationship and westward limit of younger Mesozoic and Tertiary strata unconformably upon the Carboniferous shown for the offshore areas.

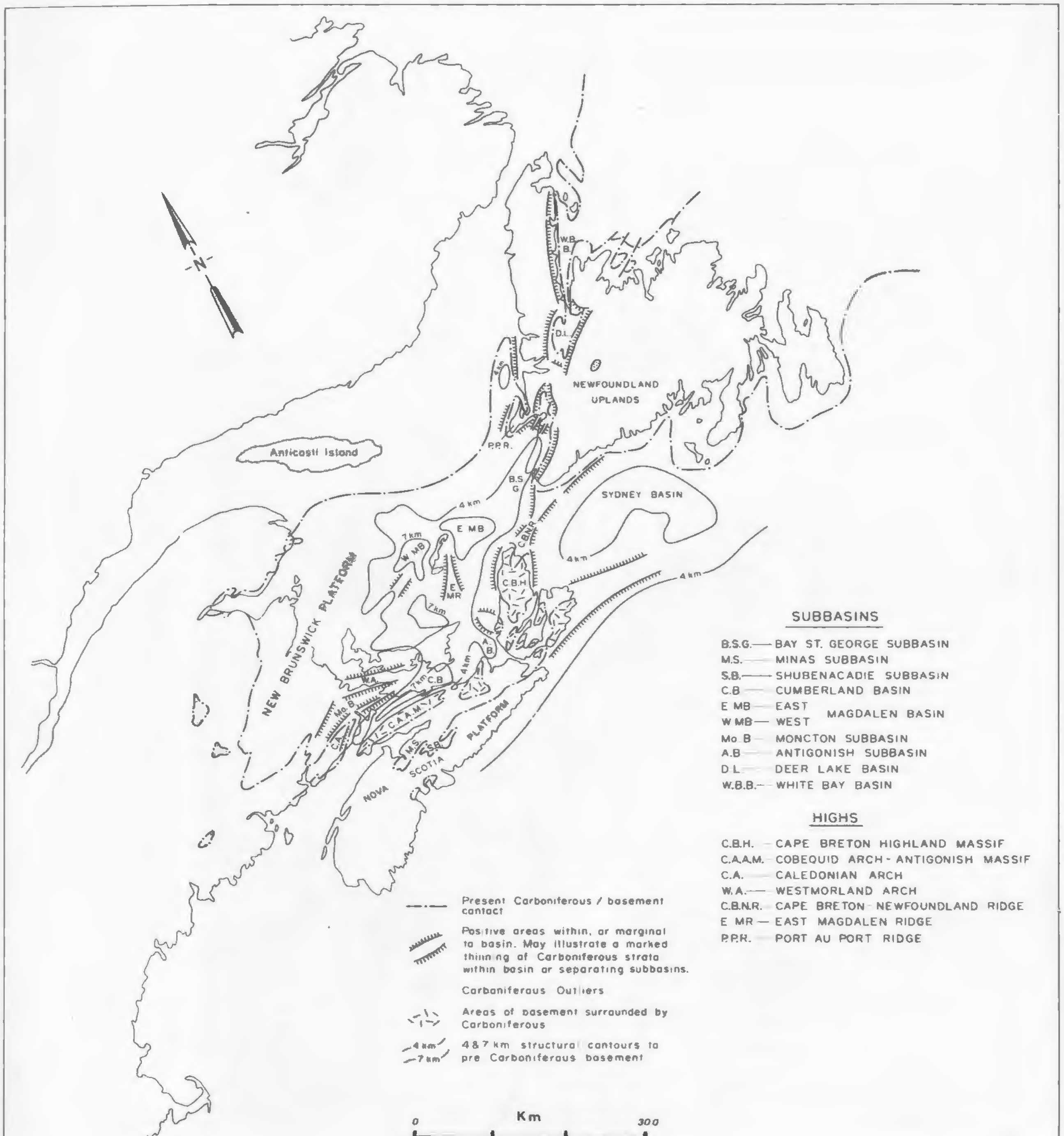


Figure 2: Distribution map of subbasins and highs (ridges and arches, basement massifs) that form the Carboniferous Maritimes Basin in Atlantic Canada. Compiled from Belt, 1968 a and b; Sheridan and Drake, 1968; Watts, 1972; Mayhew, 1974; Howie and Barss, 1975a.

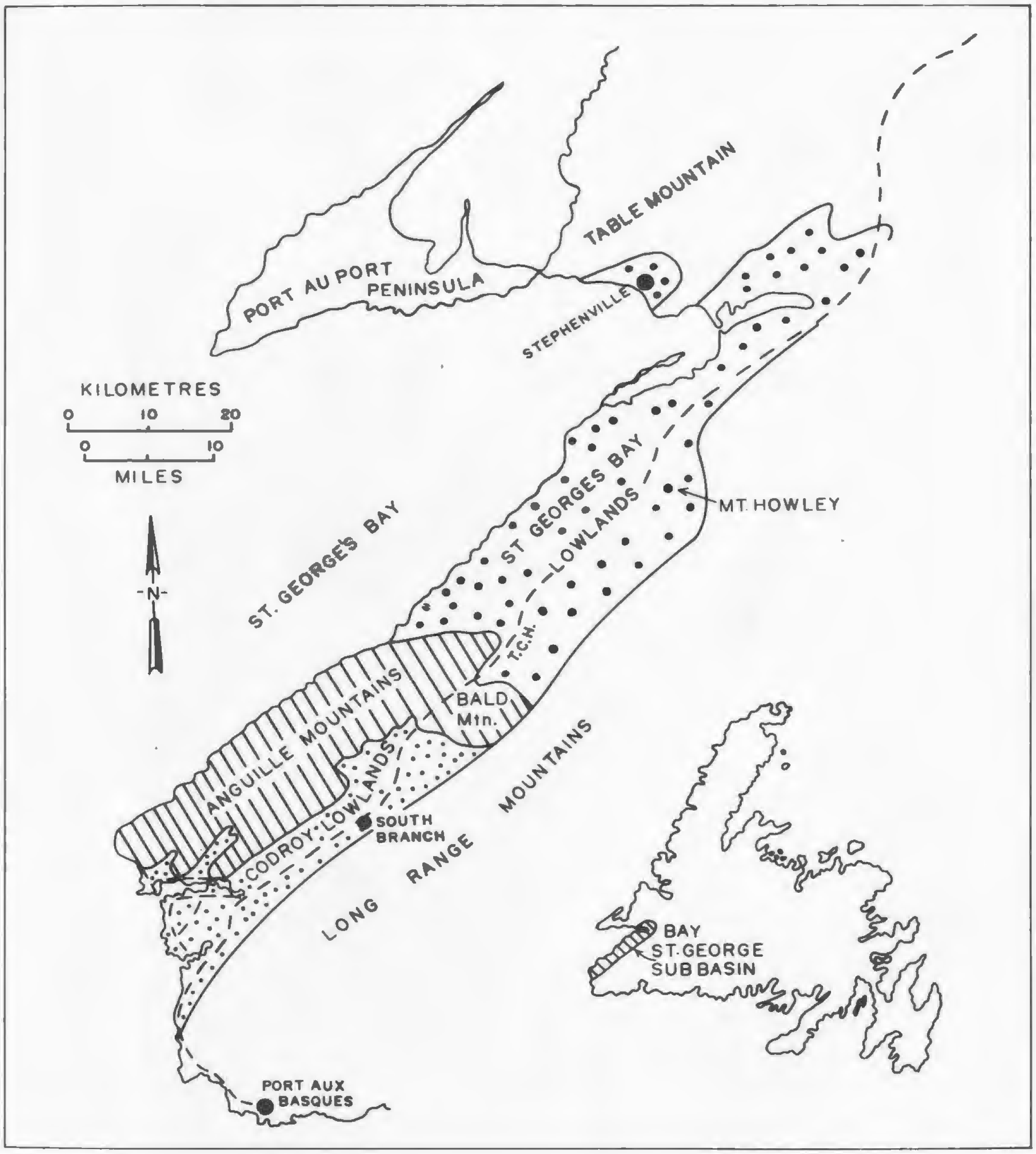


Figure 3: Major geomorphological subdivisions of the Bay St. George subbasin.
—— highways and roads.

Table I: Stratigraphic nomenclature used by present and previous workers for rock units in the Bay St. George Subbasin.

Murray (1873)	Hayes and Johnson (1938)	Bell (1948)	Baird (1949)		Baird and Cote (1964)	Utting (1966)	Knight, this report			STAGES: NOVA SCOTIA	STAGES: EUROPE	STAGES: NORTH AMER.
			Codroy Section	Ship Cove-Fischells Section			Codroy lowlands - Anguille Mountains		St. George's Bay lowlands			
COAL MEASURES OR PENNSYLVANIAN	BARACHOIS SERIES	BARACHOIS SERIES	BARACHOIS SERIES	BARACHOIS SERIES	BARACHOIS GROUP	BARACHOIS GROUP	BARACHOIS GROUP		BARACHOIS GROUP	PICTOUAN CUMBER-LANDIAN	WEST-PHAL-IAN C B	PENN-SYL-VAN-IAN
Div. E Green and red sandstone, brown and black shale, coal beds with under-clays							upper coal-bearing sequence		"undivided"	RIVERS-DALIAN	A	
Div. D Brown and red sandstone, conglomerate; brown, black, and green micaceous shale, plant fossils		Searston Beds	Searston Beds	Searston Beds	including Searston Beds	Searston Beds	Searston Formation			CANSOAN	NAMUR-IAN	
WINDSOR MARINE SERIES	CODROY SERIES	CODROY SERIES	CODROY SERIES	CODROY SERIES	CODROY GROUP		CODROY GROUP		CODROY GROUP			
								Robinsons River Fm.	Robinsons River Fm.			
Div. C Variegated red, green and dark marls with Windsor marine fauna, sandstone	Woody Point sandstone	Woody Head beds	Woody Point beds	Highlands sandstone	UPPER		Woody Cape Formation	Overfall Brook Member Mollichignick Member	Brow Pond Lentil			
	Woody Point shales and limestone	Woody Cove beds	Woody Cove beds	Crabbs and Jeffrey's limestone and inter-bedded sandstones and siltstones					Highlands Member	W I N D S O R IAN	V I S E A N	MISS-ISS-IPP-IAN
		Crabbs and Jeffrey's limestone						Jeffrey's Village Member	Jeffrey's Village Member			
Div. B Gypsum, green, red and brown shales, black and dark gray limestone	Black Point limestone, Codroy shales and gypsum	Black Point limestone Gypsiferous Zone	Codroy beds including the Black Point limestone	Codroy beds including Heatherton, Fischells, Cormorant limestones	LOWER		Codroy Road Formation		Codroy Road Formation			
		Ship Cove limestone	Ship Cove limestone	Ship Cove limestone			Ship Cove Formation		Ship Cove Formation			
Div. A	ANGUILLE SERIES	ANGUILLE SERIES	ANGUILLE SERIES	ANGUILLE SERIES	ANGUILLE GROUP		ANGUILLE GROUP		ANGUILLE GROUP	H O R T O N IAN	TOUR-NAIS-IAN	
Conglomerate plus flaggy sandstone and greenish shales	Snakes Bight shale, Cape Anguille sandstone		Seacliffs sandstone	Fischells conglomerate Seacliffs sandstone	Seacliffs Formation		Spout Falls Formation		Fischells conglomerate member (Spout Falls Formation)			
							Friars Cove Formation					
			Snakes Bight shale	Snakes Bight shale	Snakes Bight Formation		Snakes Bight Formation					
			Anguille sandstones	Anguille sandstones	Cape John Formation		Kennels Brook Formation			PRE-HORTON	FAMEN-NIAN	DEV-ONIAN

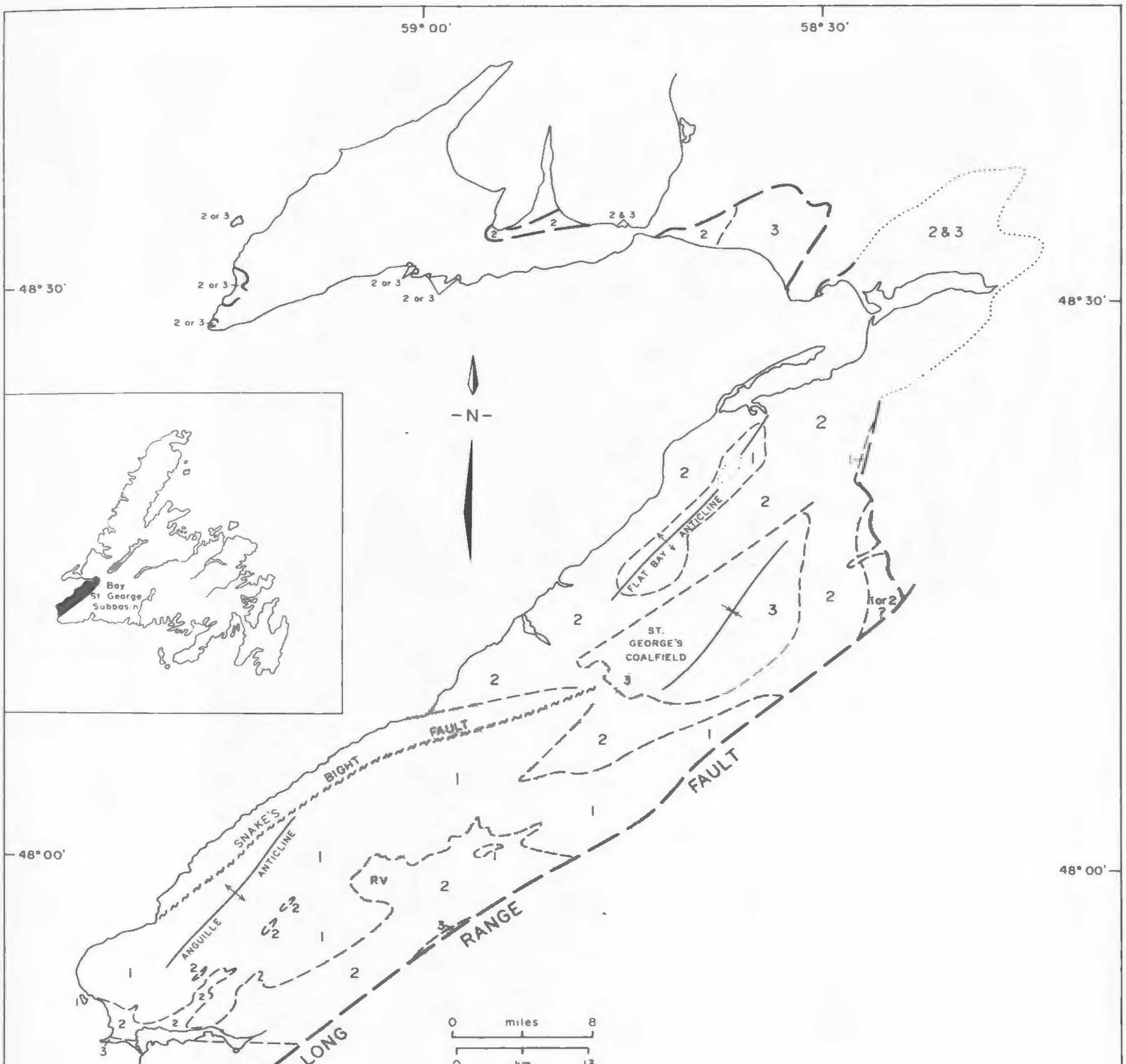


Figure 4: Distribution of groups in the Bay St. George subbasin: 1 - Anguille Group; 2 - Codroy Group; 3 - Barachois Group. (R.V. - "round valley")

Plate 1: Cliff section just north of Low Brook, Snakes Bight. Section includes some thick bedded sandstones (lithofacies C) interbedded with bundles of turbidite sandstone and shale (lithofacies B), some of which thicken upwards. Cliff about 60 m high.

Plate 2: Lithofacies A black shale and laminated mudstone at base of a coarsening-upward sequence within the Snakes Bight Formation at Cape Anguille. Note steady upward increase of thin sandstone and siltstone beds.

Plate 3: Thick bedded, massive sandstones (lithofacies C) forming top of coarsening-upward sequence in the Snakes Bight Formation at Cape Anguille. The sandstones overlie interbedded shale and flute-bearing turbidite sandstone which in turn overlie planar, flat bedded, very fine sandstone, siltstone and thin black shale.

Plate 4: Dolomite beds and laminae in black mudstones (lithofacies A) from the top of the Snakes Bight Formation near Cape Anguille lighthouse. The sediments are deformed by syn-sedimentary folds.

Plate 5: Siltstone-shale beds of lithofacies B, Snakes Bight Formation. The shales exhibit gently dipping upward-facing cleavage. Thicker beds at base are fine sandstones, internally deformed, with irregular bases; unnamed brook near Snakes Bight.

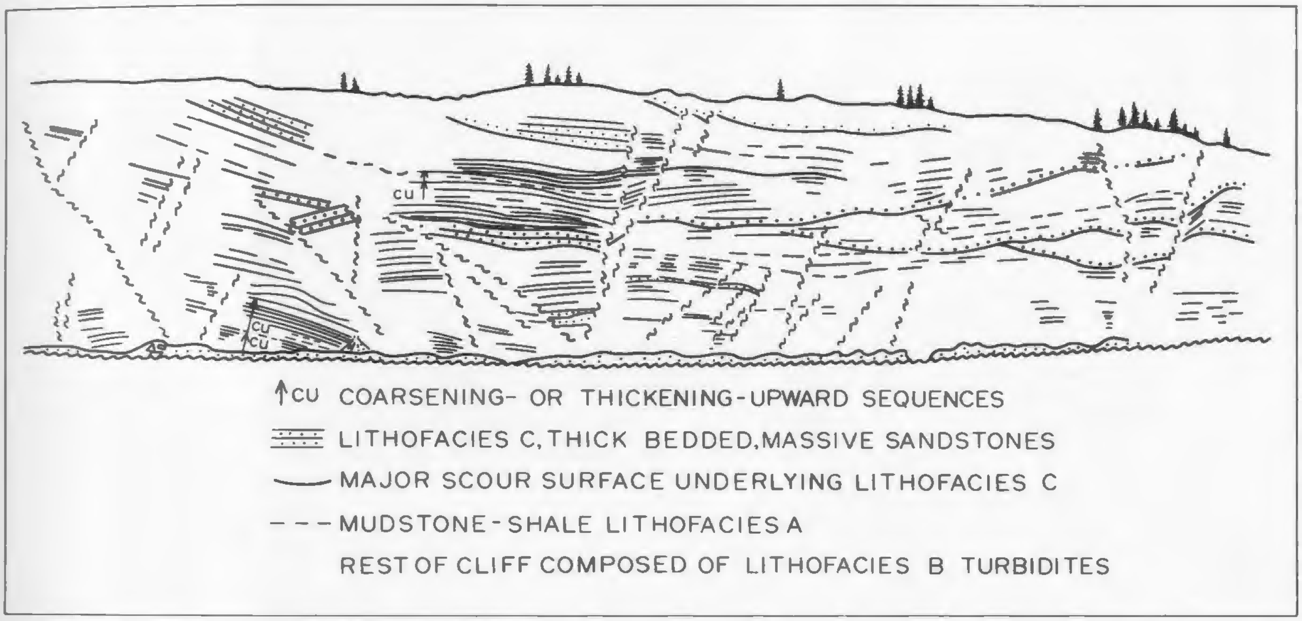


Figure 6: Line drawing from photographs of cliffs overlooking Snakes Bight, just north of mouth of Low Brook. Strata of the Snakes Bight Formation contain major erosion surfaces that are mostly overlain by lithofacies C sandstones interspersed through thick sequence of turbidite sandstones (lithofacies B).

Plate 6: Lithofacies E intraformational mixtite consisting of small fragments of laminated mudstone and dolomite set in a brown, calcareous sandy mudstone matrix. Snakes Bight Formation, unnamed brook overlooking Snakes Bight.

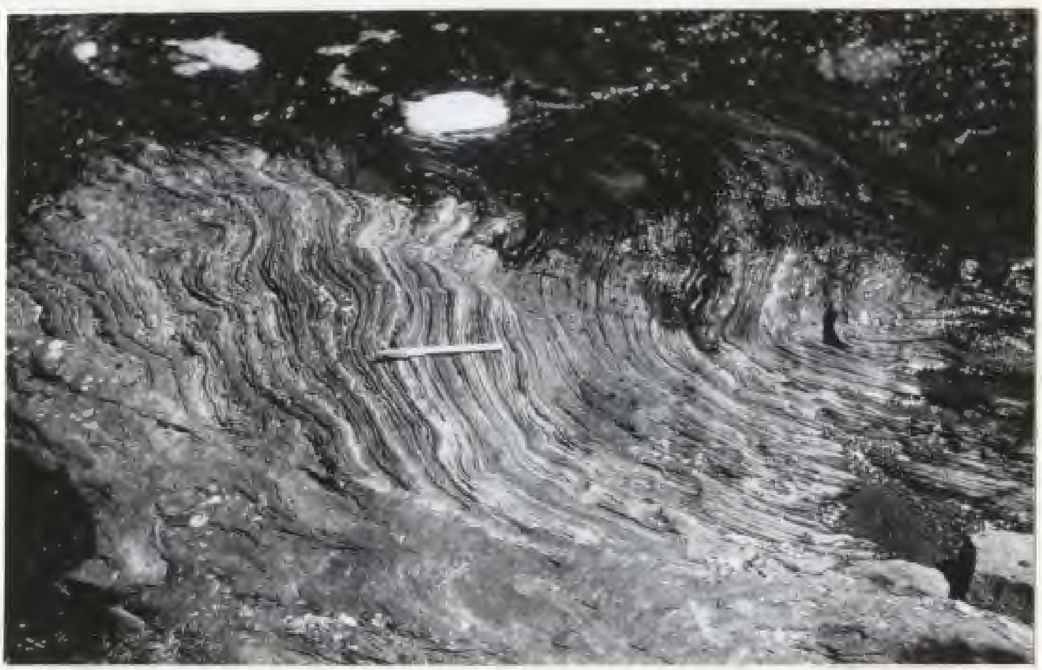


Plate 7: Large fragment of laminated mudstone and dolomite (lithofacies A) in intraformational mixtite, Snakes Bight Formation, unnamed brook near Snakes Bight.

Plate 8: Flat lying synsedimentary fold deforming sandstone bed within interbedded sandstones and shales of lithofacies B of the Snakes Bight Formation. The strata lies just beneath a thick sequence of lithofacies C and B sandstones. Locality same as in plates 6 and 7.

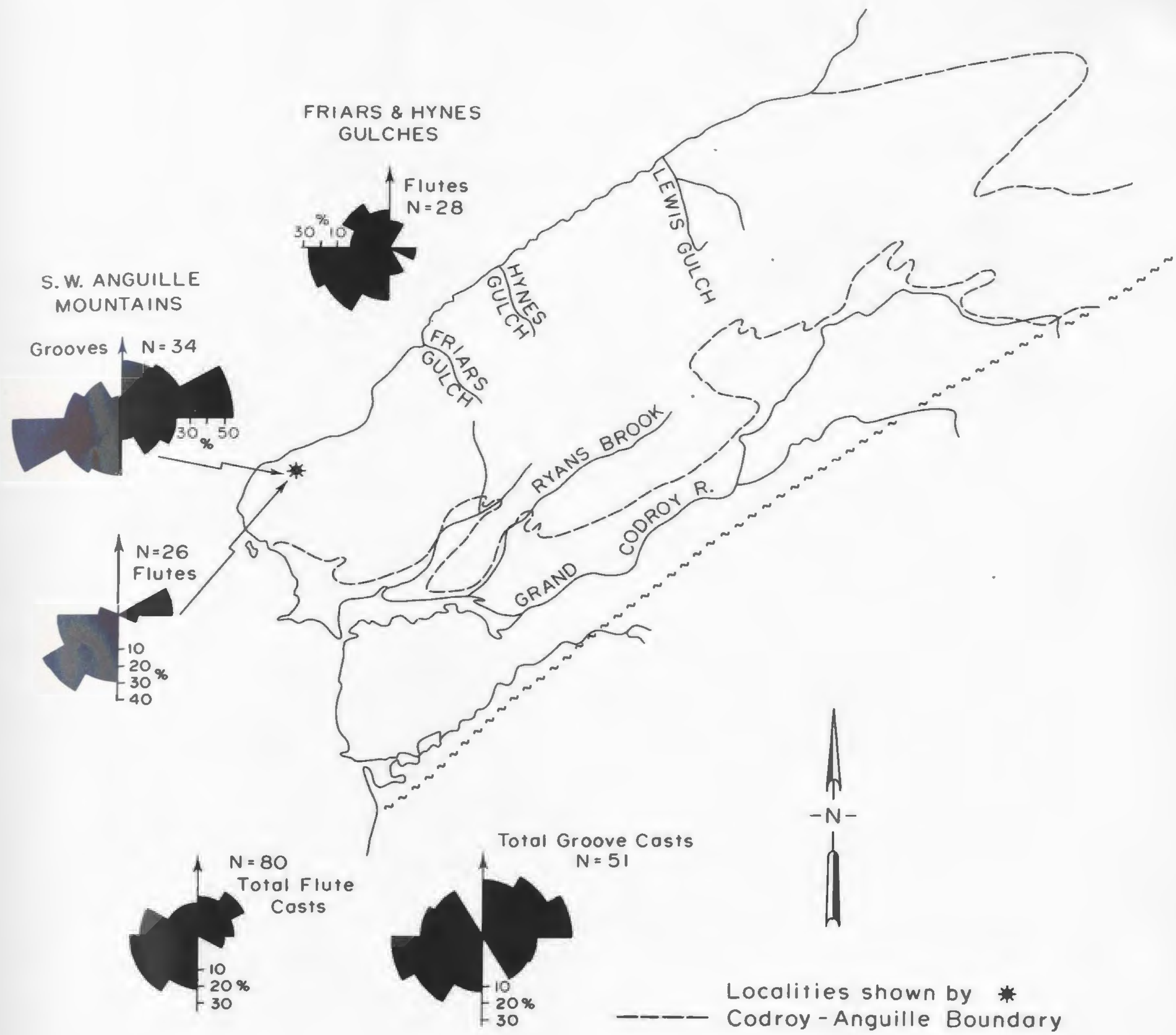


Figure 7: Paleocurrent distributions in the Snakes Bight Formation.

Plate 9: Thick, chaotic conglomerate beds at the base of the Friars Cove Formation. The conglomerates overlie an erosion surface that cross cuts underlying thin bedded sandstones, siltstones and shales of the Snakes Bight Formation; contact is dotted. Fish huts, near Cape Anguille lighthouse.

Plate 10: Intercalated sandstone and conglomerate at the base of the Friars Cove Formation, near Cape Anguille lighthouse. Sandstone is thinly stratified and overlies hummock top of conglomerate bed. It is overlain erosively by the next conglomerate which contains rip-ups of the sandstone.

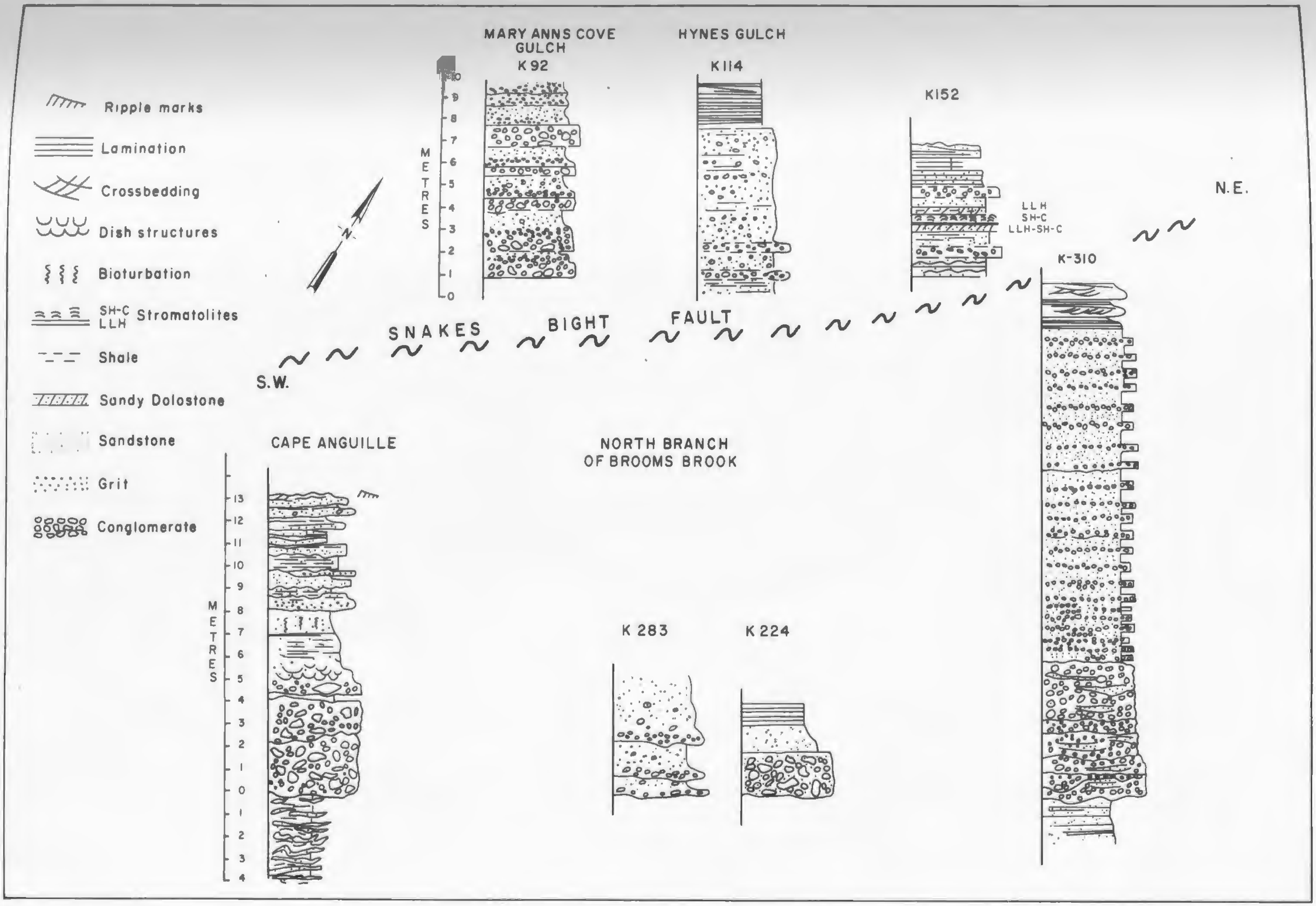


Figure 9: Sections measured through conglomerate - sandstone lithofacies at base of Friars Cove Formation.

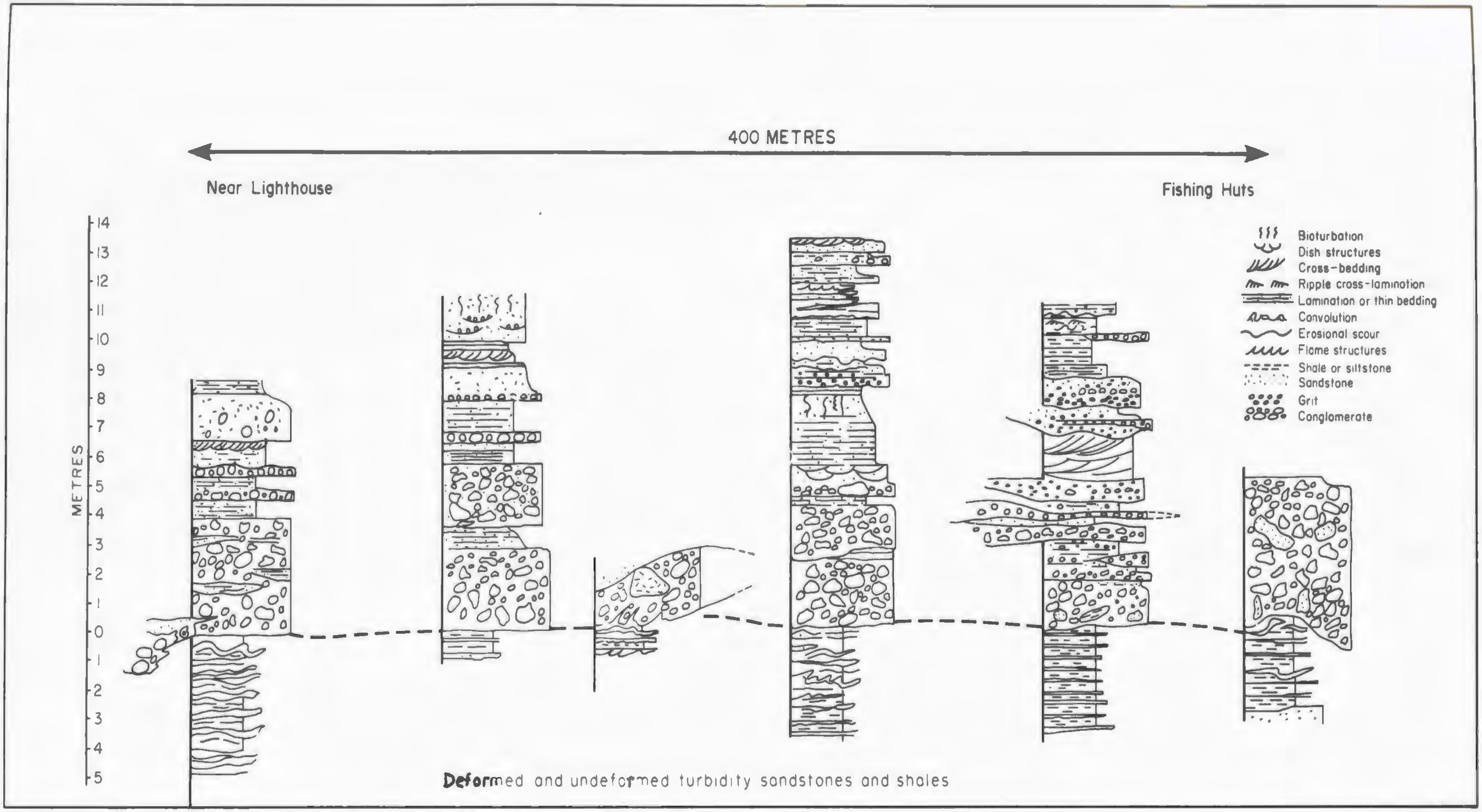


Figure 10: Detailed sections through basal conglomerates of the Friars Cove Formation at Cape Anguille.

Plate 11: A thick, lenticular conglomerate of lithofacies A, Friars Cove Formation, cross cutting underlying sandstone and thin shales of the Snakes Bight Formation, Cape Anguille lighthouse. Boulders and large pebbles concentrated at top of plug. A pebble dike injects underlying sandstone bed at A. Measuring stick 1 m long.

Plate 12: Normally graded conglomerate lying between sandstones of the Friars Cove Formation, Cape Anguille lighthouse. Grading may reflect two pulses of conglomerate, a finer pebble layer deposited over coarser material. Note irregular base of conglomerate with pebbles sunk into underlying sandstones. Overlying sandstone is massive. Measuring stick 1 m long.

Plate 13: Inversely graded conglomerate from basal beds of the Friars Cove Formation with erosive base into underlying sandstone bed. Hammer is 28 cm long. Cape Anguille lighthouse.

Plate 14: Graded pebbly sandstone bed, lithofacies A, Friars Cove Formation, Cape Anguille lighthouse. The bed consists of a structureless division at base overlain with sharp transition by laminated sandstone. Scale 1 m long.

Plate 15: Crossbedded sandstone overlying erosively graded, massive sandstone that lies above a bed of small-pebble conglomerate. Cape Anguille lighthouse.

Plate 16: Pillar structures in a sandstone of lithofacies A, Friars Cove Formation, Cape Anguille lighthouse.

Plate 17: Well bedded, planar-stratified sandstone of lithofacies B, Friars Cove Formation. South branch of Brooms Brook.

Plate 18: Lithofacies B sandstone bed, Friars Cove Formation, located at the northwest end of Codroy Island. The sandstone begins with a scoured base which is overlain by structureless and then slightly deformed, planar-stratified sandstone.

Plate 19: Pebble layer lying gradationally within massive and stratified, very coarse and gritty sandstones at the base of the Friars Cove Formation, Friars Gulch. Large quartzite pebbles lie across upper boundary of pebble bed. Sequence is inverted. Note cluster of pebbles in stratified sandstone in the top left of the plate.

Plate 20: Straight, rhomboid and interference ripple-marks in thin bedded, rippled sandstones (lithofacies C, Friars Cove Formation), Codroy Island.

Plate 21: Yellow weathering dolostones covering rippled sandstone bed, Codroy Island. Location as in Plate 20.

Plate 22: Burrows and chevron trails criss-cross a flat bedding plane of a silty sandstone if lithofacies D, Friars Cove Formation, west shore of Codroy Island. Large mudcracks are also present.

Plate 23: Close-up of chevron trail shown in Plate 22.

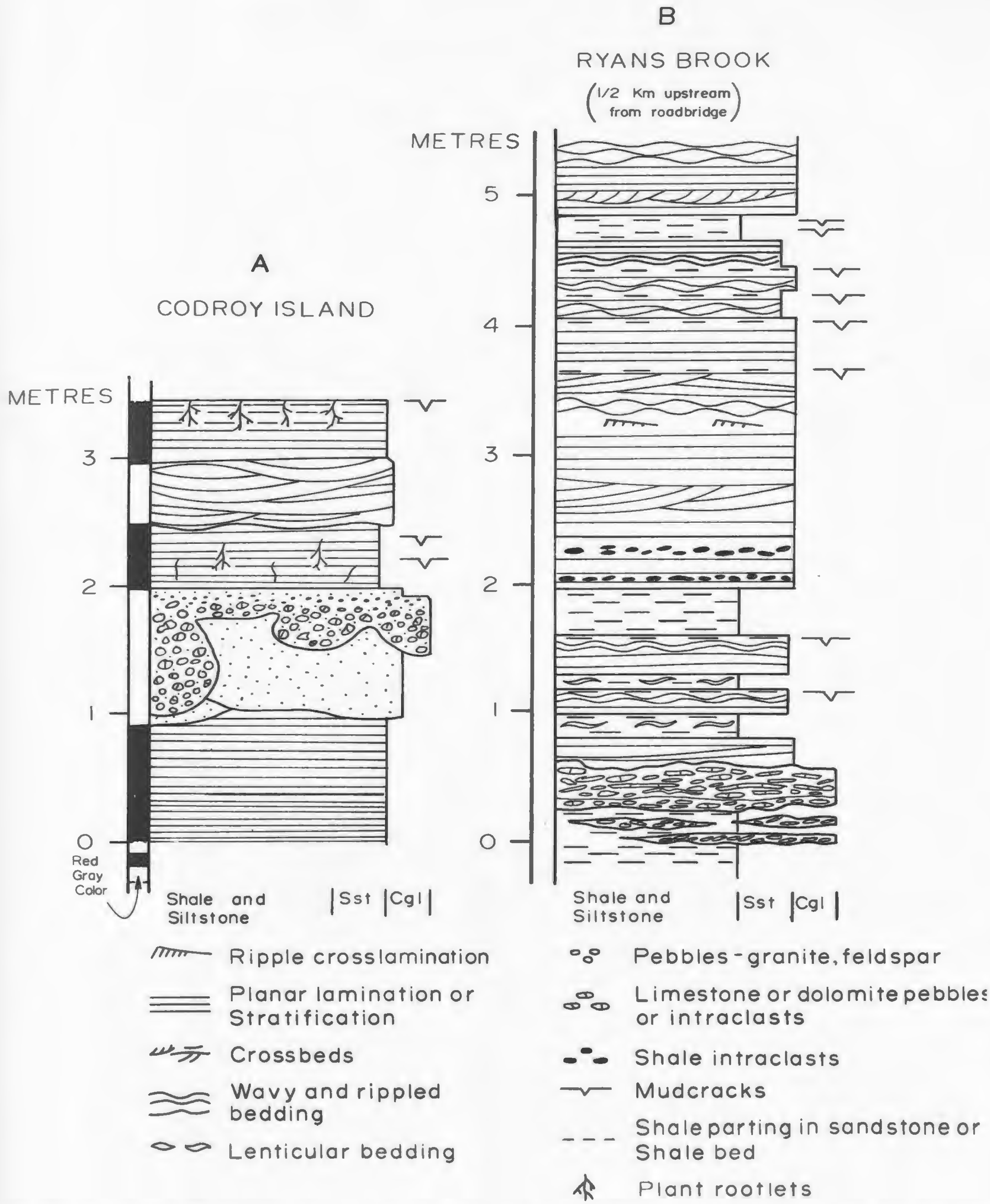


Figure 12: Sections illustrative of lithofacies E (section A) and lithofacies G (section B) near the top of the Friars Cove Formation in the south of the subbasin.

Plate 24: A conglomerate composed mostly of small feldspar and ferruginous pebbles crosscutting green arkosic sandstones, lithofacies E, Friars Cove Formation, west shore of Codroy Island. The erosive base of the conglomerate was subsequently deformed by loading.

Plate 25: Laminated dolomite overlying calcareous mudstone with small algal structure near base. Intraclastic, sandy dolomite occurs above the laminated dolomites. Lithofacies F, Friars Cove Formation, unnamed stream northeast of Hynes Gulch.

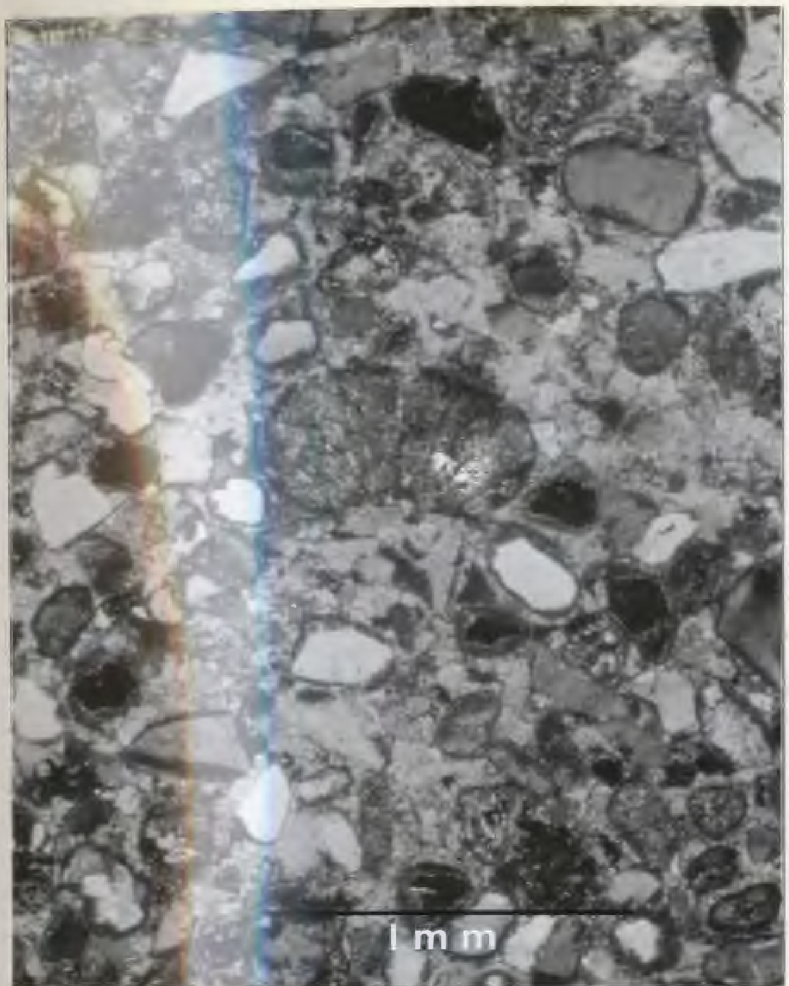


Plate 26: Photomicrograph of dolomite containing dolomite-coated sand grains and some carbonate grains set in a spar cement. Lithofacies F, Friar's Cove Formation.

Plate 27: Photomicrograph of ooids, carbonate intraclasts and silt grains set in sparry cement. Intraclasts enclose ooids which were previously bound and cemented before reworking. Same locality as Plate 26.

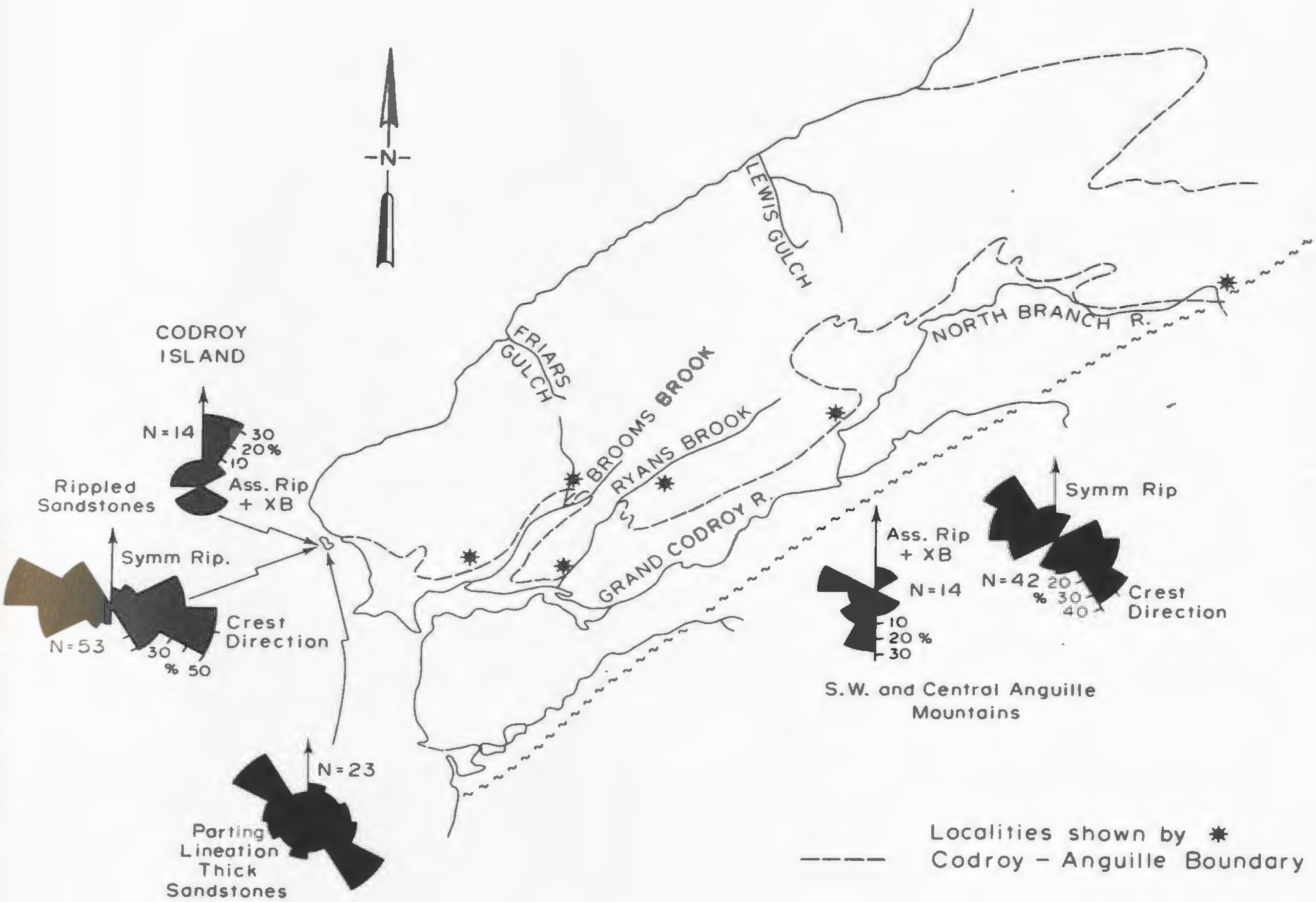


Figure 13: Paleocurrent distributions in the Friars Cove Formation.

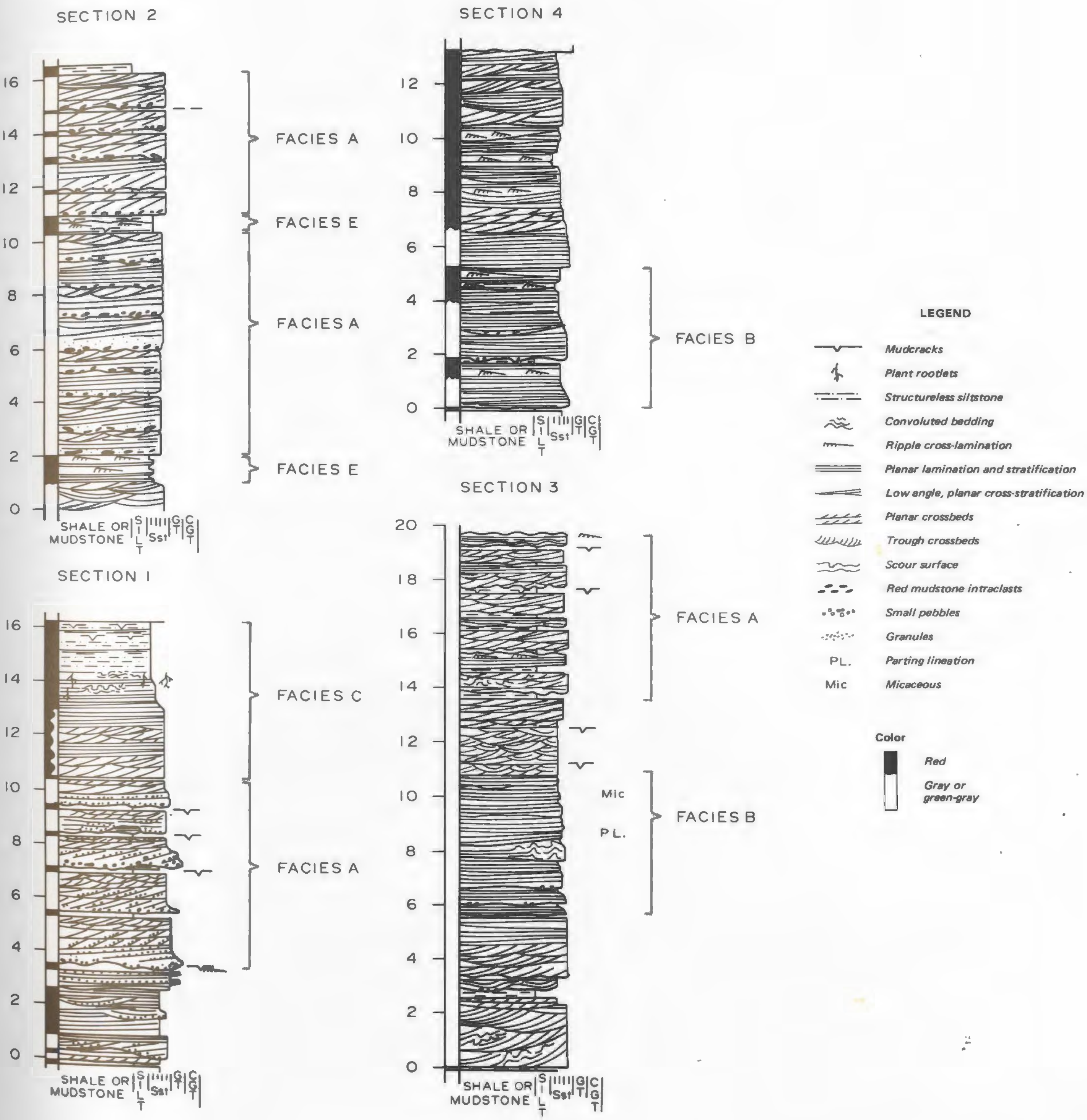


Figure 14: Detailed sedimentological sections in the Spout Falls Formation at Friars Cove.

Plate 28: Cliffs on the north side of Hynes Cove showing the characteristic sheet-like geometry of the red and grayish-red sandstones of the Spout Falls Formation along the south shore of St. George's Bay. Some of the beds clearly lense out and a number of scours are present beneath sandstone beds. Beds are inverted and young to the left.

Plate 29: Planar-stratified, gray sandstones of lithofacies B, Spout Falls Formation, interbedded with thin red siltstone (lithofacies E). Trans Canada Highway, north of Highlands River. Scale one metre.

Plate 30: Very large scale, planar crossbeds overlain by cosets of large scale, trough crossbeds (lithofacies D), in steeply dipping beds of Spout Falls Formation; beds young to left. The huge crossbeds lie against a broad deep channel scour. The top of the cross-sets was eroded by a planar scour which was in turn overlain by the large crossbeds. Location Lewis Gulch.

TECTONIC EVENT HUMBER ARM ALLOCHTHON HIGHLANDS	TECTONIC EVENT IN SUBBASIN	BAY ST. GEORGE SUBBASIN			TECTONIC EVENT S.E. OF LONG RANGE FAULT	STAGE
			STRATIGRAPHY	SEDIMENTATION		
	Basin Deformed by Wrench, Then by Vertical Block Faulting				*Vertical Faulting or Strike-Slip Faulting*	*Stephanian? or Post-Pennsylvanian*
	Subsidence		*Barachois Group includes Searston Formation*	*Fluvial and Coal Beds* *Fluvial*	*Uplift*	*Westphalian A* *Namurian A*
	Subsidence Localized Near Long Range Fault?	CODROY GROUP	*BPL? Overfall Brook Member* *? Woody Cape Formation* *Mollichignick Member* (ROBINSONS RIVER FM)	*AF Alluvial Fan* *Fluvial + Minor Marine* *Deltaic* *AF*	*Uplift* *Uplift*	
Upland Terrain No Longer Major Detrital Source	*Subsidence in Fault-Bounded Troughs*	CODROY GROUP	— ? — ? *BPL? Highlands Member* *Upper Jeffrey's Village Member* (ROBINSONS RIVER FM)	— ? — — ? *AF Fluvial* *Mixed Fluvial + Minor Marine*	*?* *Uplift*	*Visean*
No More Lateral Displacement	*Subsidence of Several Small Subbasins and Uplift of Arches*	CODROY GROUP	*Lower Jeffrey's Village Member* (ROBINSONS RIVER FM)	*Dominantly Marine, Lesser Nonmarine*		
	Basin Widens During Last Stages of Strike Slip Fault Movement That Influenced Subbasin	CODROY GROUP	*Codroy Road Formation* *SCF*			— — ? — —
60 Km Northeastward Lateral Displacement Uplift	*Steady Basin Extension*	ANGUILLE GROUP	*BPL?* *FCM*	*AF* *AF?*		
	2nd Basin Pullapart	ANGUILLE GROUP	*Spout Falls Formation*	*Fluvial* *Rapid Basin Fill*	*Uplift + Wrench Fault Movements*	
	Snakes Bight Fault Active	ANGUILLE GROUP	*Friars Cove Formation*	*Lacustrine-Fluvial-deltaic*		*Tournaisian*
60 Km Northeastward Lateral Displacement Uplift	*Steady Basin Extension*	ANGUILLE GROUP	*Snakes Bight Formation*	*Lacustrine*		— — ? — —
	1st Basin Pullapart	ANGUILLE GROUP	*Kennels Brook Formation* — ? —	*Fluvial* *Rapid Basin Fill*	*Wrench Fault Movements*	*Famennian*

TABLE 3: *Compilation of stratigraphy, sedimentation and inferred tectonic events in the Carboniferous Bay St. George subbasin and surrounding areas.*
°°° - conglomerate; AF - Alluvial Fan; FCM - Fischells conglomerate member; SCF - Ship Cove Formation; BPL - Brow Pond lentil

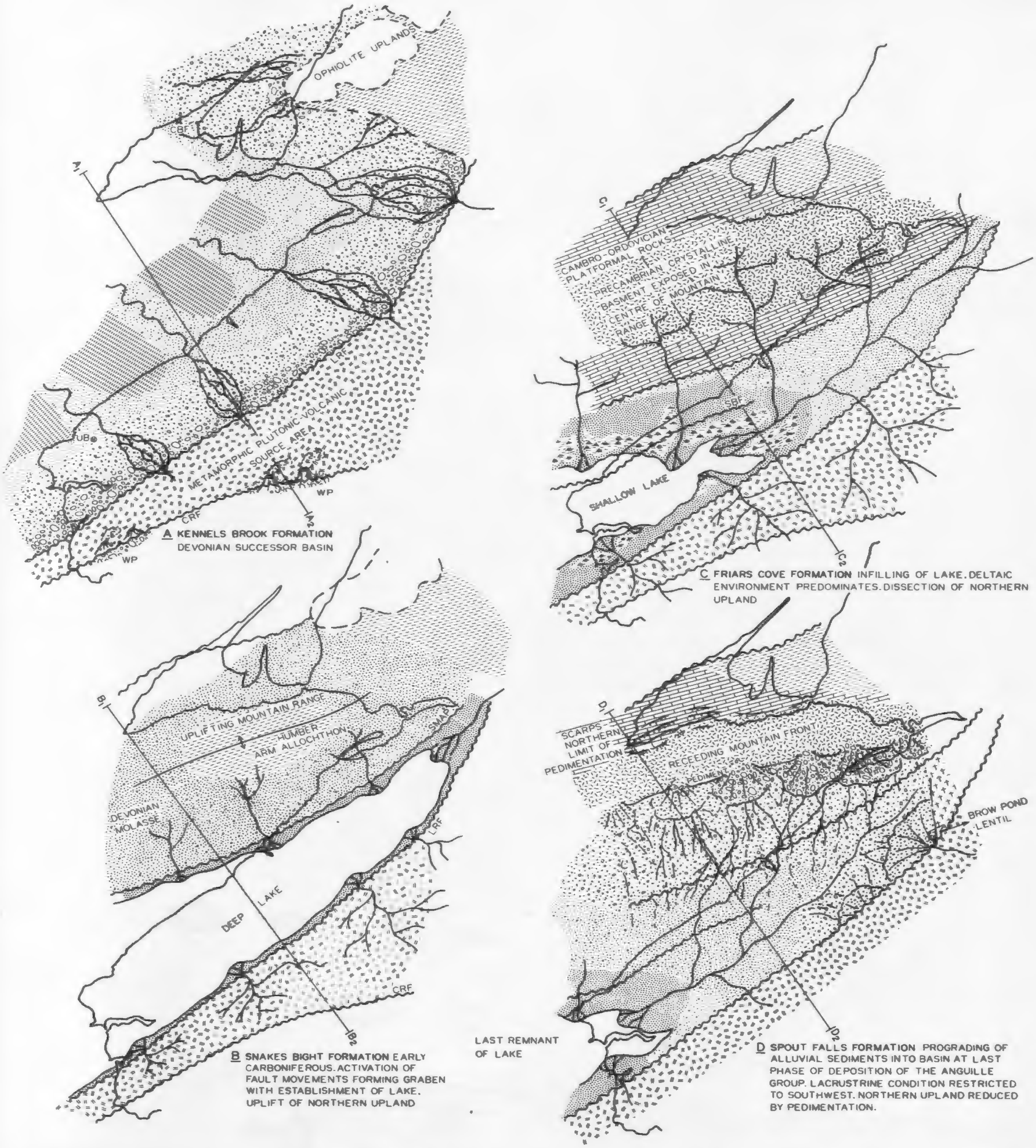
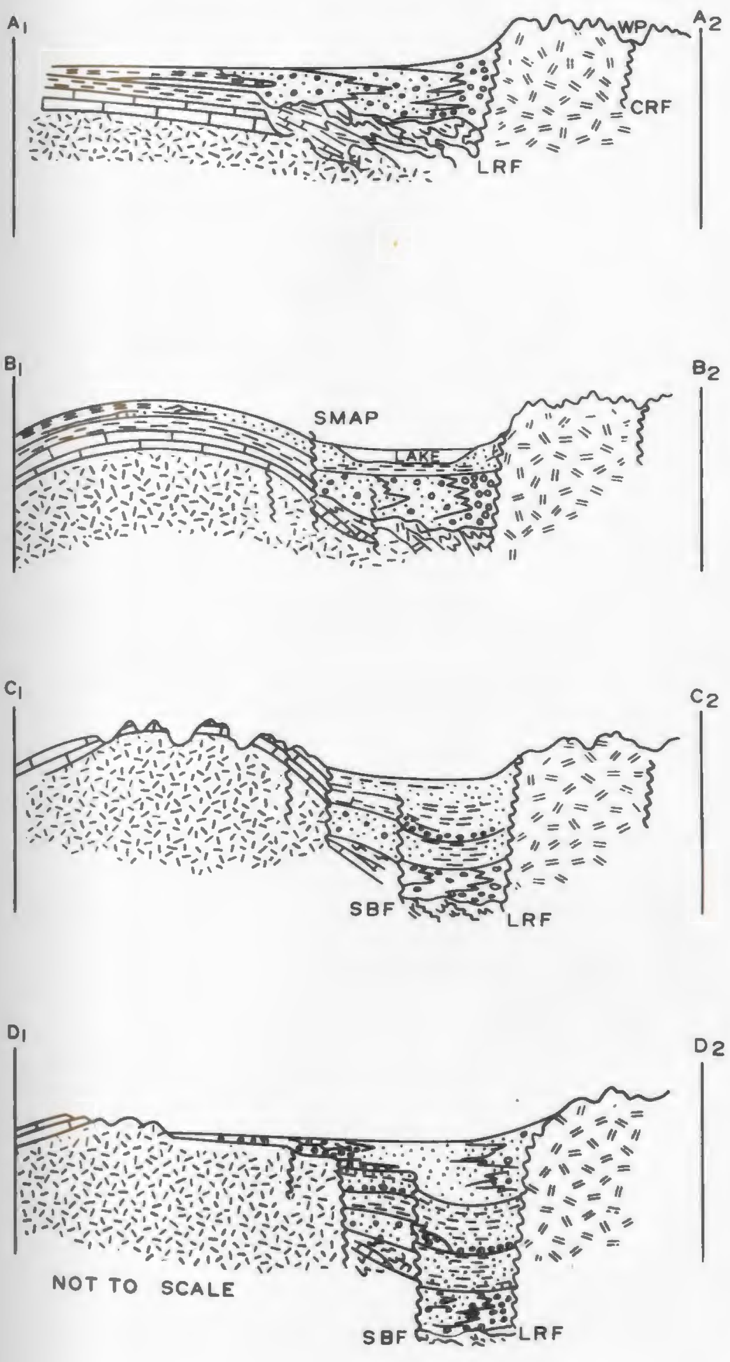


Figure 15: Possible tectono-stratigraphic model for the Bay St. George subbasin during the deposition of the Anguille Group. In this model, the subbasin developed as a narrow graben controlled largely by block faulting within the Cabot Fault system with elevation of uplands both northwest and southeast of the subbasin.



LEGEND FOR FIGURE 15

CARBONIFEROUS AND DEVONIAN SEDIMENTS

- FANGLOMERATE FACIES
- SANDY AND PEBBLY FLUVIAL FACIES
- FLOOD PLAIN FACIES
- SANDY DELTA FACIES
- DELTA PLAIN FACIES
- LACUSTRINE FACIES

BASEMENT ROCKS

- ANORTHOSITE
- PRECAMBRIAN CRYSTALLINE ROCKS
- CAMBRO-ORDOVICIAN SILICI-CLASTIC AND CARBONATE ROCKS
- SEDIMENTARY ROCKS OF HUMBER ARM ALLOCHTHON
- DEVONIAN MOLASSE
- PRECAMBRIAN TO ORDOVICIAN CRYSTALLINE METAMORPHIC AND VOLCANIC ROCKS

U B-UNION-BRINEX DRILL HOLE
CBF-CLAM BANK FORMATION
WP-WINDSOR POINT GROUP
LRF-LONG RANGE FAULT
CRF-CAPE RAY FAULT
SBF-SNAKES BIGHT FAULT
SMAP-SOUTHERN MARGIN OF APPALACHIAN PLATFORM
A_1-A_2 SECTION

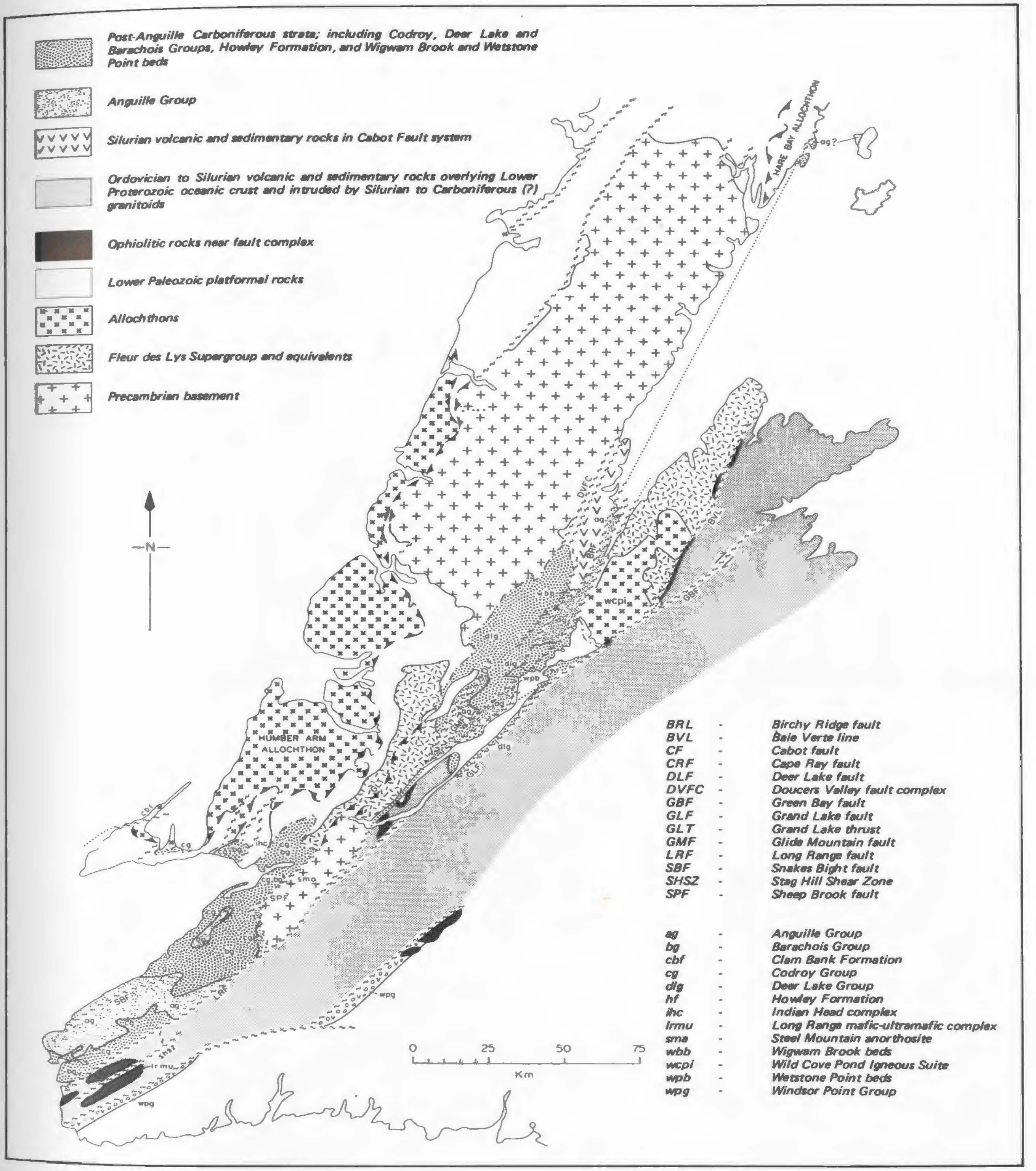


Figure 16: Main faults, distribution of geologic terranes and Carboniferous sedimentary basins associated with the Cabot Fault system in western Newfoundland. Based on geologic map of Newfoundland (Williams, 1967); modified with data from Knapp et al. (1979), Hyde and Ware (1980, 1981), Chorlton and Dingwell (1981), Smyth and Schillereff (1982), Hyde (personal communication, 1981, 1982), Hibbard (personal communication, 1981) and Knight (this report).

TABLE 4 - LITHOLOGIES AND DEPOSITIONAL ENVIRONMENTS OF FORMATIONS OF THE CODROY GROUP

NEVES et al. 1972 Miospore Zones	UTTING 1978	MAMET 1970 1968 Foraminifera Zones	BELL 1929 1948 Macro Faunal Subzones	CODROY LOWLANDS COASTAL SECTION Lithology	CODROY LOWLANDS COASTAL SECTION Environment	CODROY LOWLANDS INLAND AREAS Lithology	CODROY LOWLANDS INLAND AREAS Environment	ST. GEORGE'S BAY LOWLANDS Lithology	ST. GEORGE'S BAY LOWLANDS Environment
						ROBINSONS RIVER FORMATION		ROBINSONS RIVER FORMATION	
NC	ASSEMBLAGE II	17	E	WOODY CAPE FORMATION Green-gray mudstone and siltstone, micaceous and arkosic sandstones; black carbonates and shale, fossiliferous	Delta complex: shallow bay, delta top, delta channel, prodelta muds	OVERFALL BROOK MEMBER Red arkosic sandstone, minor conglomerate, some fine gray beds, gray pebbly mudstones Disconformable?	Humid alluvial fan, braided stream		
VF		16_s	D			MOLLICHIGNICK MEMBER Red siltstone and sandstone, gray micaceous and arkosic sandstone, gray and red muddy, pebbly sandstones and conglomerate, gray mudstones and dolomites, fossiliferous carbonates, caliche limestone	Alluvial deposits: River channel, overbank, alluvial fan; Shallow lacustrine Shallow marine; Pedogenic carbonate	HIGHLANDS MEMBER Red and minor gray, yellow sandstone, red siltstone, minor conglomerate. Some caliche, limestone Conformable	Alluvial deposits: meander river, overbank, alluvial fan to east and north; Some aeolian sands; Possibly marine at base
		16_i	C					JEFFREY'S VILLAGE MEMBER Red siltstone, fine red sandstone, gray sandstone; gray shale and marine sandstone, fossiliferous and algal carbonates; gray mudstone, shale, sandstone; gypsum, anhydrite, halite, potash salts Contact covered	Distal alluvial plain, shallow streams, playa flats; Shallow lagoon and marine shelf, algal banks; Deltas; Hypersaline lagoon, salinas, mud flats
NM	ASSEMBLAGE I		B	JEFFREY'S VILLAGE MEMBER Red siltstone and brecciated limestones Conformable	Shallow shoreline and distal alluvial plain				
		15		CODROY ROAD FORMATION Black carbonates, gray shale and mudstone, gypsum/anhydrite, red siltstone and thin sandstone	Marine shelf and lagoon, hypersaline lagoon and mudflats, alluvial plain	Biohermal limestone, gypsum, red siltstone, gray mudstone and black carbonate	Open marine, reefs, hypersaline lagoon, alluvial plain and playa flat	Biohermal limestone and gypsum-anhydrite, gray shales and evaporitic mudstones replaced northward by gypsum and anhydrite	Reefs, hypersaline shallow lagoon, sabkha flat
			A	SHIP COVE FORMATION Lithology Laminated limestone, shaly limestone, gypsiferous, some oolitic and oncolitic units, limestone breccia, minor sandstone, gray, green and red shale		Environment Shallow subtidal to intertidal carbonate flat		General continuity throughout basin except near Fischells Brook where deposits of gray shale and thin sandstones are associated	

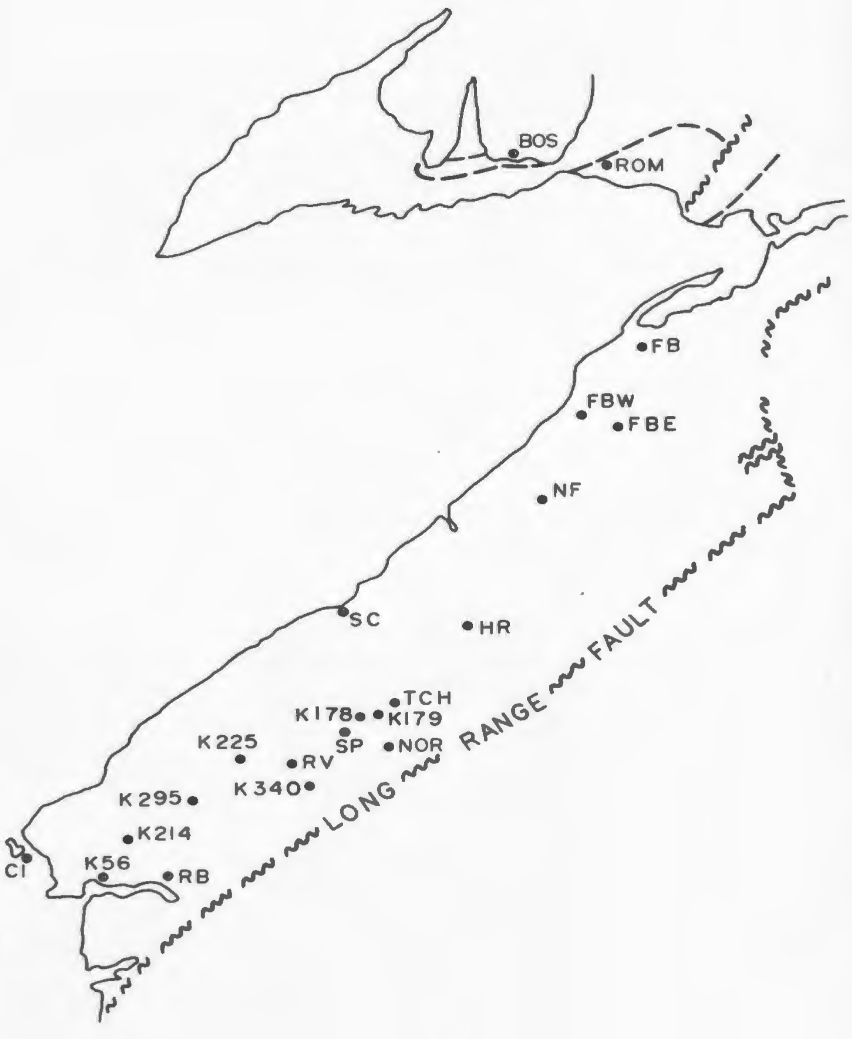
LEGEND for Figure 18

- *Moldic laminite*
- *Shaly limestone*
- *Laminite*
- *Packstone*
- *Sandstone*
- *Shale*
- *Conglomerate*

- *Red Siltstone*
- *Sandstone*
- *Shale*
- *Limestone*

FC	*Flute Cast*
LC	*Load Cast*
BM	*Brush Mark*
ST	*Stromatolite*
	Intraclasts
	Oncolites
	Pellets, ooids
	Fossils
	Ostracods
	Brachiopods
	Bioturbation
	Molds after gypsum
	Fenestral porosity
	Mudcracks
	Fractures, silt-filled cracks deformed by compaction
	Tepee Structures
	Deformed bedding or lamination
	Ripple cross-lamination
	Lamination - planar or wavy
	Crossbeds
	Current direction
	Crest of symmetrical ripple mark
	Parting lineation

CI	CODROY ISLAND
RB	RYANS BROOK
RV	ROUND VALLEY
SP	SANDY'S POOL
NOR	NORANDA SHOWING
TCH	TRANS CANADA HIGHWAY
SC	SHIP COVE
HR	HIGHLANDS RIVER
NF	NORTHERN FEEDER
FBW	FISCHELLS BROOK WEST
FBE	FISCHELLS BROOK EAST
FB	FLAT BAY QUARRY
ROM	ROMAINES BROOK
BOS	BOSWARLOS



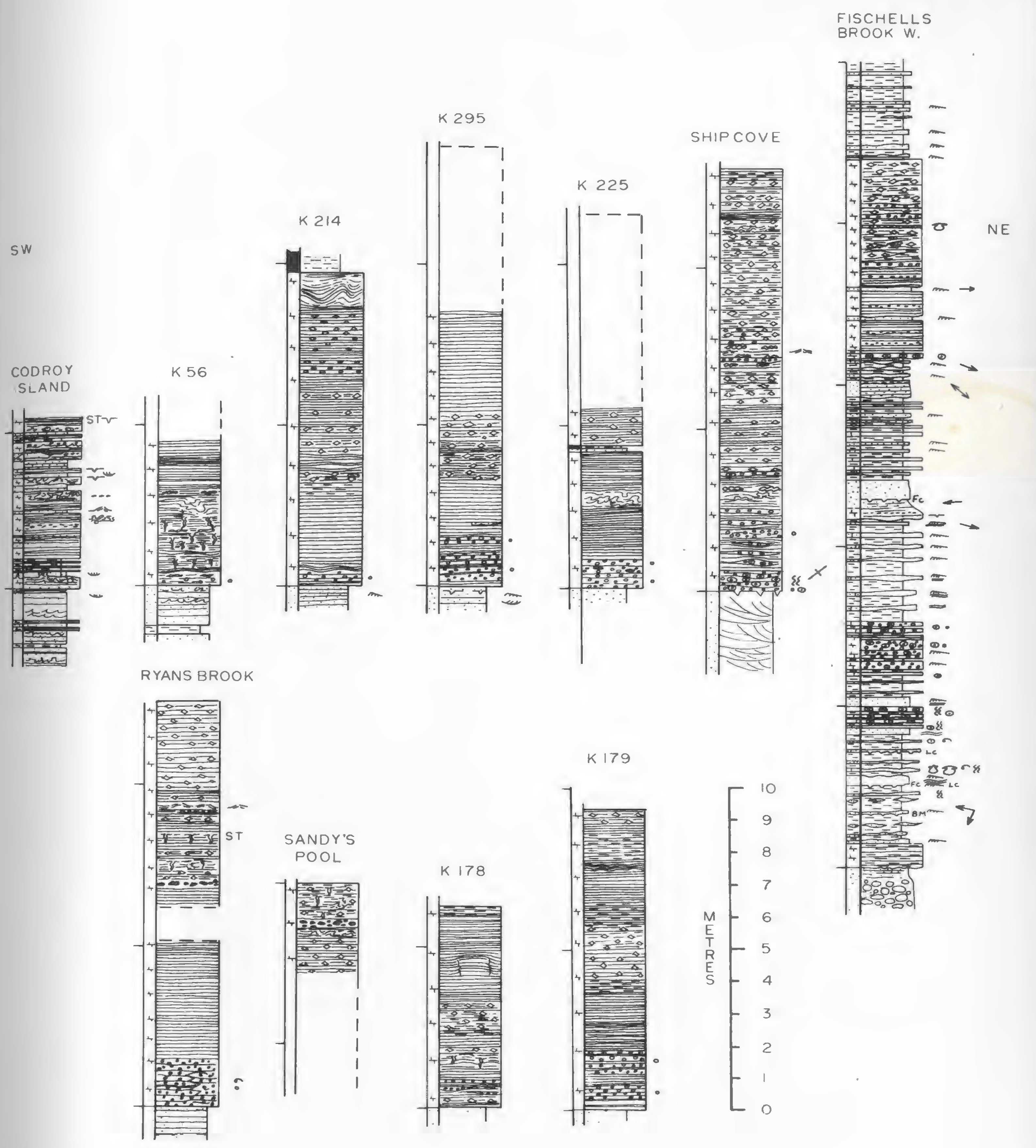


Figure 18: Sections through the Ship Cove Formation in the Bay St. George subbasin.

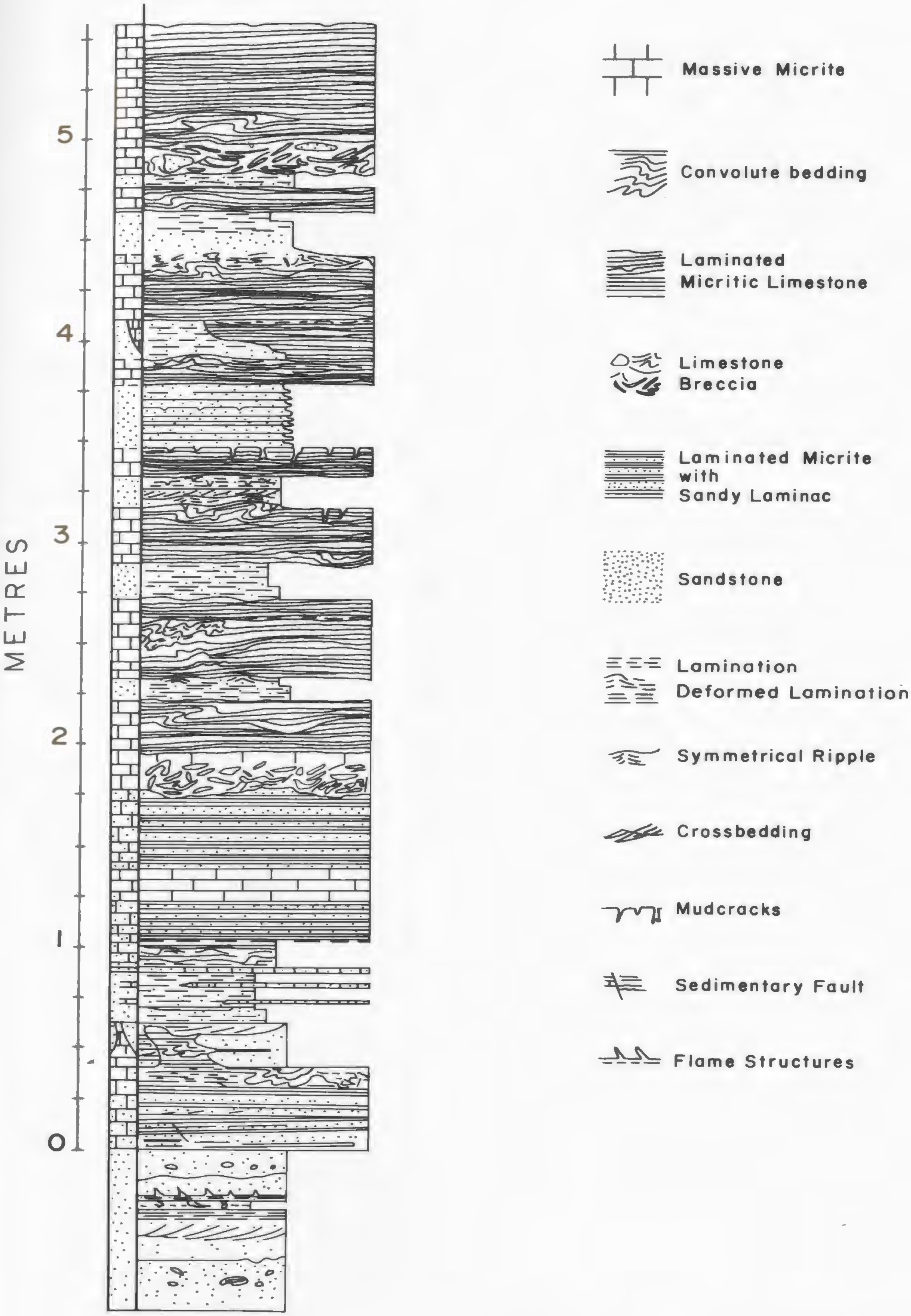


Figure 19: Detailed section of the Ship Cove Formation on Codroy Island.

TABLE 5 : COMPILATION OF AVAILABLE GEOLOGICAL DATA FOR THE SHIP COVE FORMATION

SW	SOUTHERN ZONE HIGH INTERTIDAL		CENTRAL ZONE SUBTIDAL TO INTERTIDAL TO HIGH INTERTIDAL								NORTHERN ZONE MARINE DOMINATED SUBTIDAL TO LOW INTERTIDAL					NE
Facies Structures Fauna	Codroy Island	K 56	Ryans Brook	K 214	K 225	K 340	K 295	Sandy's Pool	K 178	K 179	Ship Cove	Highlands River	Northern Feeder	Fischells River East Cobbs Pool	Fischells River West	Port au Port
Facies F Sandstone	X				X								X	X	X	
Facies D Limestone breccia	X															
Facies E Oolitic limestone											X		X	X		
Facies G Gray shale, red siltstone				X^{Rd}				X^{Gy}					X^{Gy}	X^{Gy}	X^{Gy}	
Facies C Moldic argillaceous and shaly laminite	X		X	X	X			X	X	X	X	X				
Structures in Facies C: Mudcracks								/								
Structures in Facies C: Ripple drift											/	NO INFORMATION				
Structures in Facies C: Stromatolites			/					/								
Structures in Facies C: Pellet packstone				/	/			/								
Facies B Laminite	X	X	X	X	X	X			X	X	X		X	X	X	
Type 1 Light and dark colored				/	/	/	/	NO INFORMATION	/	/						
Type 2 Silty	/	/		/	/						/					
Type 3 Fenestral		/		/	/						/		/	Poor in Fenestra		
Structures in Facies B: Mudcracks	/	/									/					
Structures in Facies B: Gypsum						/								/		
Structures in Facies B: Deformation (Tepee, etc)	/	/		/	/		/				/				/	
Structures in Facies B: Stromatolites	/	/		/					/							
Structures in Facies B: Ooids		/												/		
Structures in Facies B: Fossils														/		
Structures in Facies B: Calcispheres														/		
Structures in Facies B: Trace fossils														/		
Structures in Facies B: Cements														/		
Facies A Pellet or skeletal packstone			X	X	X	X	X			X	X	X	X	X	X	X
Structures in Facies A: Oncolites			/	/			/			/	/	/	/	/	/	/
Structures in Facies A: Intraclasts											/					
Structures in Facies A: Ooids														/	/	
Structures in Facies A: Fossils			/							/	/	/	/	/	/	/
Structures in Facies A: Trace fossils												/	/	/		/
Structures in Facies A: Cements			/							/		/		/	/	
Sedimentary rocks overlying formation		Red Siltstone		Red Siltstone							Gray Shales	Grey Shales			Gypsum & Limestone	
Facies at base of formation	B	B	A	A	A (Thin)	A	A		Bor C	A	E or A	A	A	A	A	A
Base type overlying red (Rd) or gray (Gy) sandstone or conglomerate of Anguille Group	Gradational Sst Gy	Sharp Sst Gy	Sharp Sst Gy	Sharp Sst Gy	Sharp Sst Gy	Sharp Sst Gy	Sharp Sltst Gy		Sharp Sst Rd Gy	Sharp Sst Gy & Rd	Sharp Slst Rd	Sharp Sst Rd	Sharp Clg, Sst, Gy	Sharp Cgl, Sst, Gy	Sharp Cgl, Sst, Gy	Sharp Cgl, Gy

Plate 31: Large, low-amplitude ripple-marks formed by segregation of coarse and fine carbonate grains in lithofacies A of the Ship Cove Formation, Ship Cove.

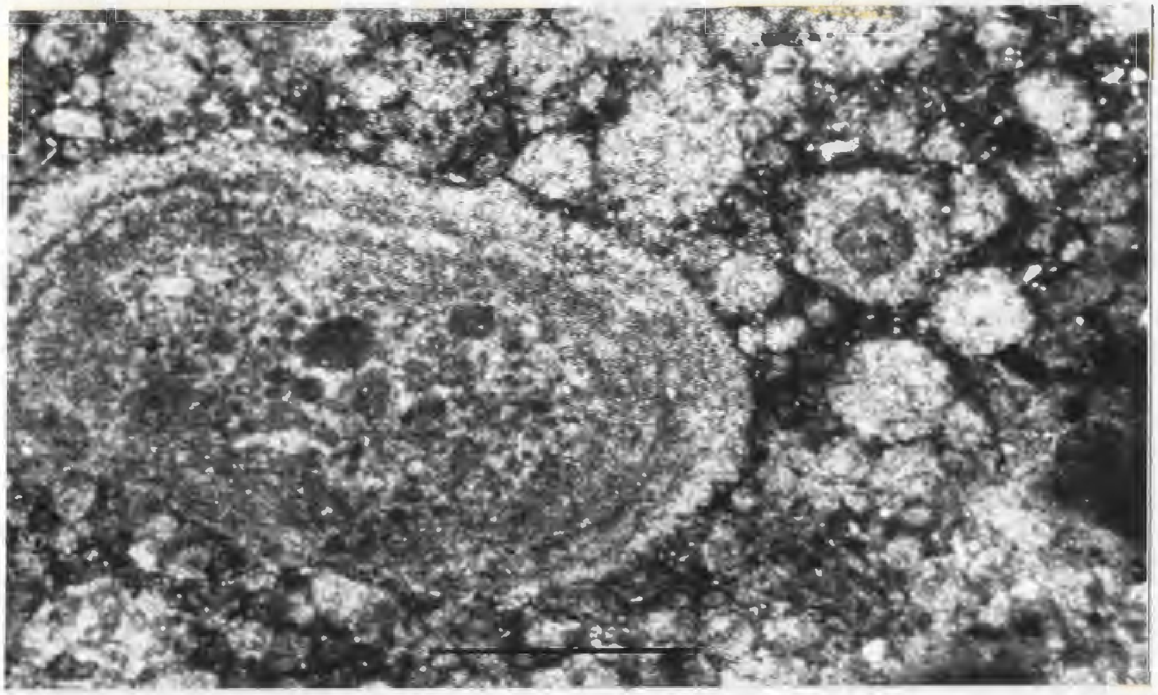


Plate 32: Photomicrograph of oncolitic pellet packstone (lithofacies A) of the Ship Cove Formation from Highlands River. Oncolite has a peloid core.

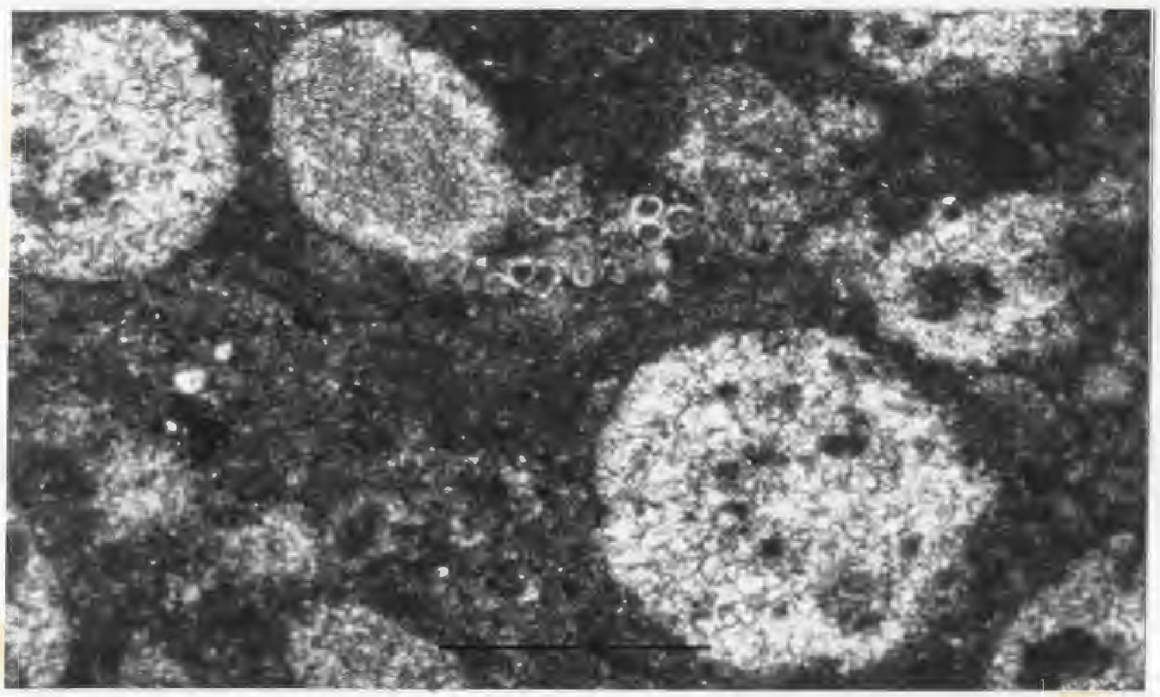


Plate 33: Clear microspar replacing spherical nonskeletal (possibly pellet) grains in wackestone, associated with a small cluster of "coccoid-like" algal spheres, lithofacies A, Ship Cove Formation, Fischells Brook.

Bar-1mm.

Plate 34: Lithofacies B laminites of the Ship Cove Formation at K-295 showing some thin layers of packstone (arrow) and local convolution of lamination.

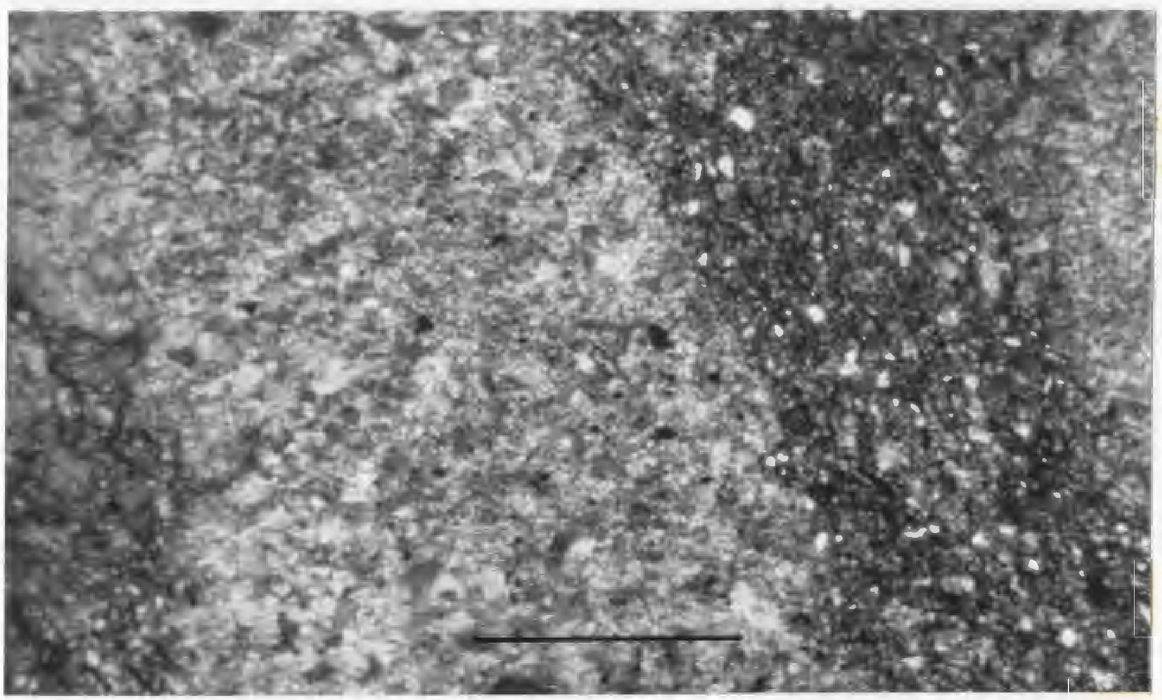
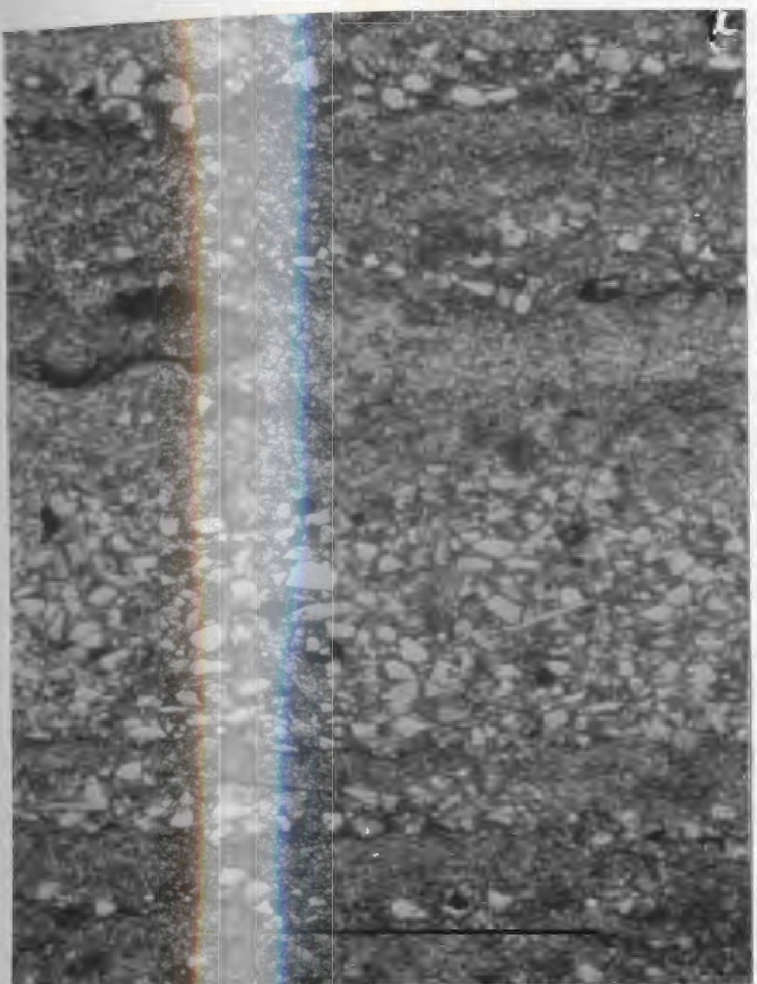


Plate 35: Type 1 laminite, lithofacies B of the Ship Cove Formation composed of clear, microspar laminae overlain by dark, carbonaceous, silty laminae. Locality K-375.

Bar-1mm.



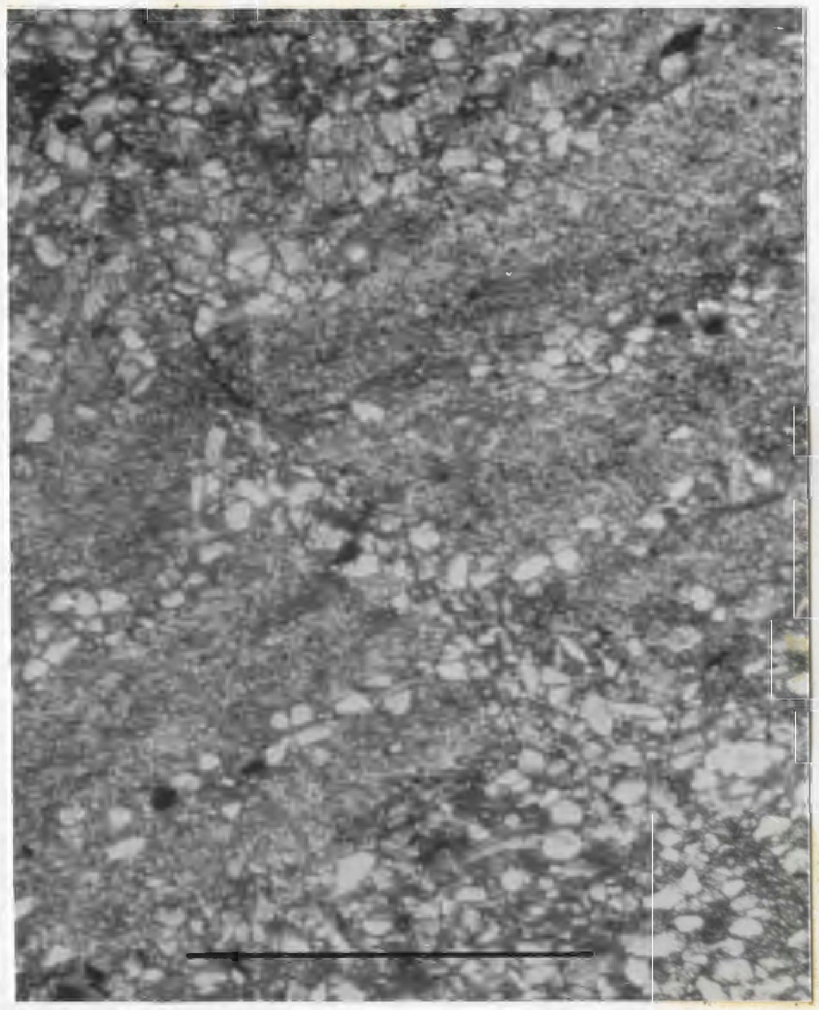
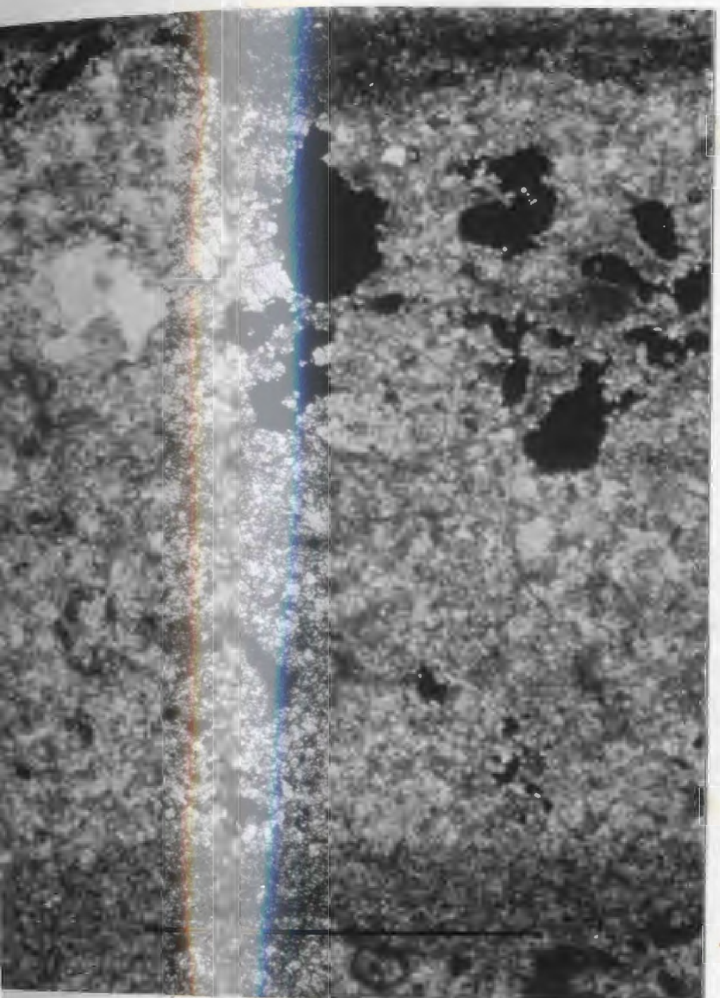


Plate 36: Silty laminite of lithofacies B of the Ship Cove Formation from locality K-56 showing siltstone laminae grading up into silt-free clear to dark microspar or micrite.

Plate 37: Fracture in silty laminite of lithofacies B, Ship Cove Formation, filled by silt grains from overlying layer. Locality K-56.

Bar-1mm.



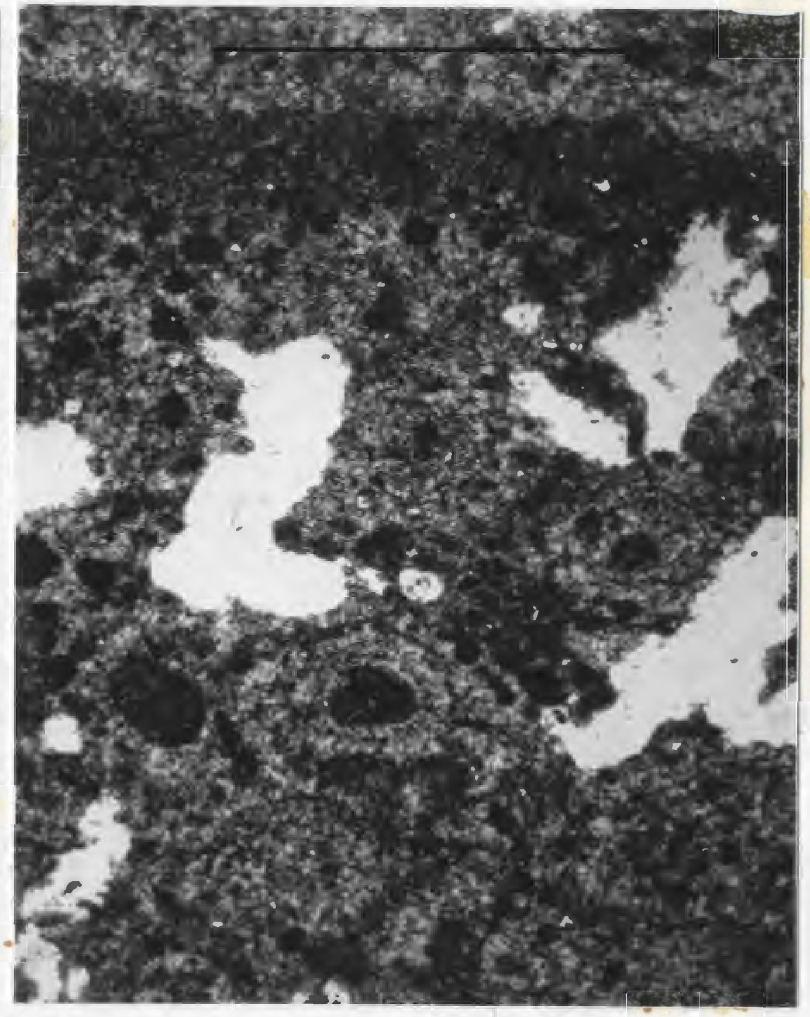


Plate 38: Type 3, carbonate-fenestral laminite of lithofacies B, Ship Cove Formation, K-56. It is silt-free, with microspar passing upwards to a fenestra-rich layer (f) overlain by a dark, carbonaceous, micritic cap.

Plate 39: Oolite grains visible in a fenestral-rich laminite that immediately underlies the laminites of Plate 38.

Bar-1mm.

Plate 40: Spherical-shaped algal structures in the Ship Cove Formation, Codroy Island. The stromatolites are flat topped, of low elevation and mudcracked.

Plate 41: Highly-deformed laminated limestones of the Ship Cove Formation, Codroy Island.

Plate 42: Very large diameter algal structure on bedding plane in laminite of the Ship Cove Formation, north side of the "round valley," Codroy lowlands. It is overlain by cross-laminated dolomitic, argillaceous limestone containing moldic porosity after dissolved gypsum crystals.

Plate 43: Facies D, limestone breccia overlying interbedded sandstone and laminite, Ship Cove Formation, Codroy Island. The breccia lies non-erosively upon the sandstone, which is locally buckled. The hummocky top is draped by laminite. Rounded sandstone clasts occur with the platy laminite lithoclasts.

Plate 44: Stratified sandstone with some laminite lithoclasts lying in channel eroded in laminite and locally undercutting laminite, Ship Cove Formation, Codroy Island. Bedded sandstone with 1-2 cm laminite partings at bottom of plate.

Plate 45: Bedded gypsum, of the Codroy Road Formation, Flat Bay gypsum mine, showing dark dolomitic laminae between white gypsum layers that are composed of coalesced nodules.

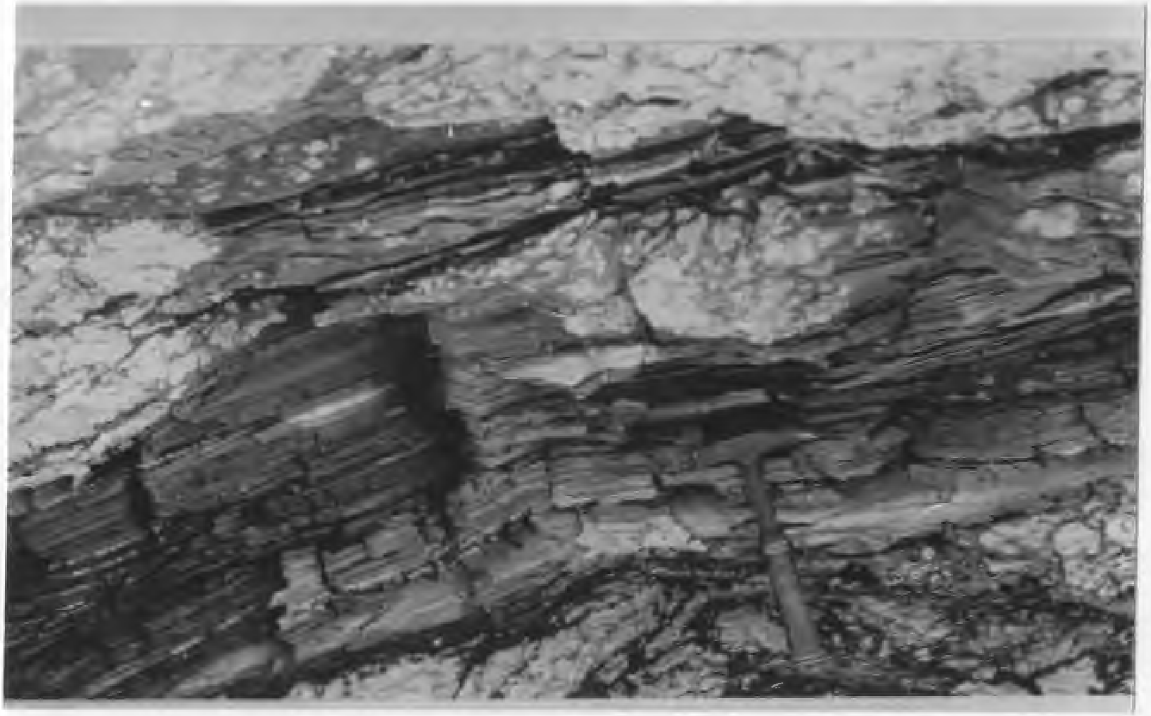


Plate 46: Thick layer of "Ship Cove Formation-type" laminite set between two thick beds of white gypsum, Codroy Road Formation, Fischells Brook. Nodular gypsum clearly grew displacively in laminite.

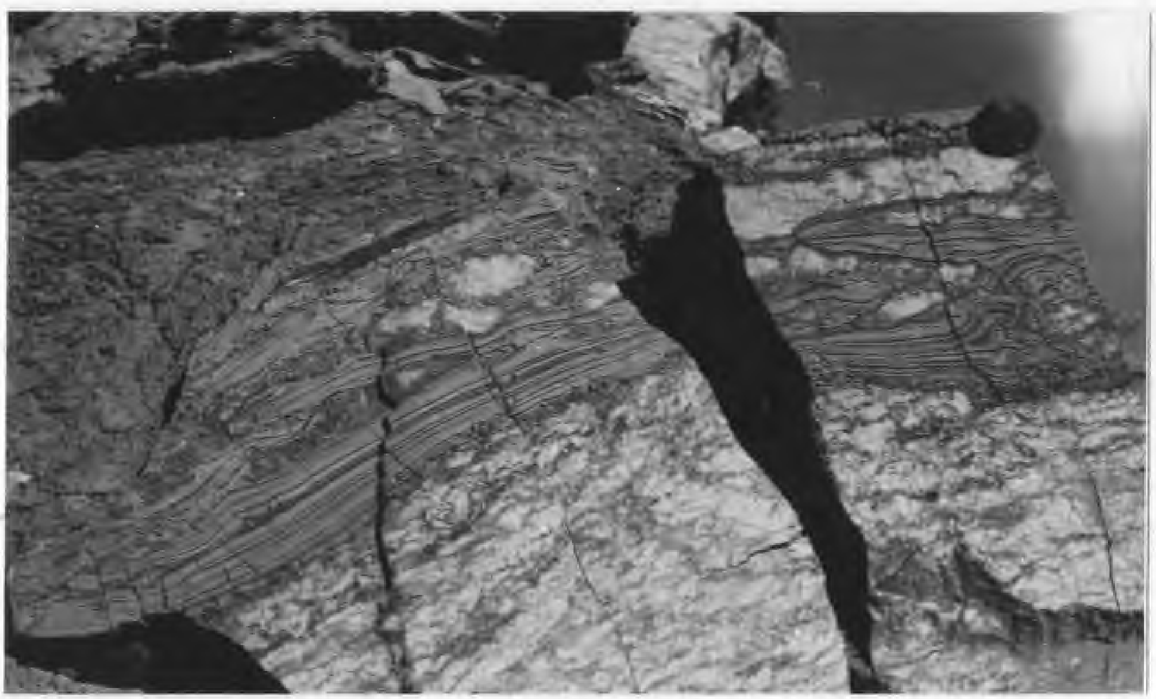


Plate 47: Nodular to contorted bedded gypsum with dolomite streaks interbedded with thin bedded, deformed argillaceous dolomite containing folded and overthrust bedding and small, fluffy gypsum nodules. Codroy Road Formation, Flat Bay gypsum mine. Lense cap for scale, 6 cm wide.

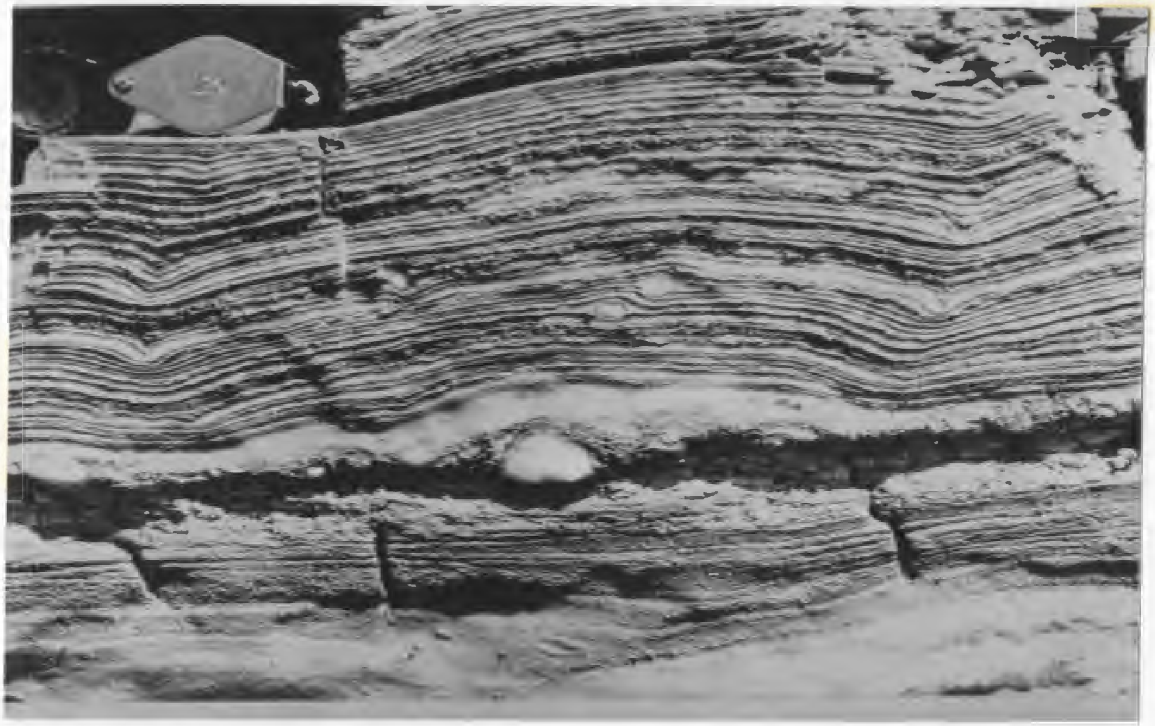
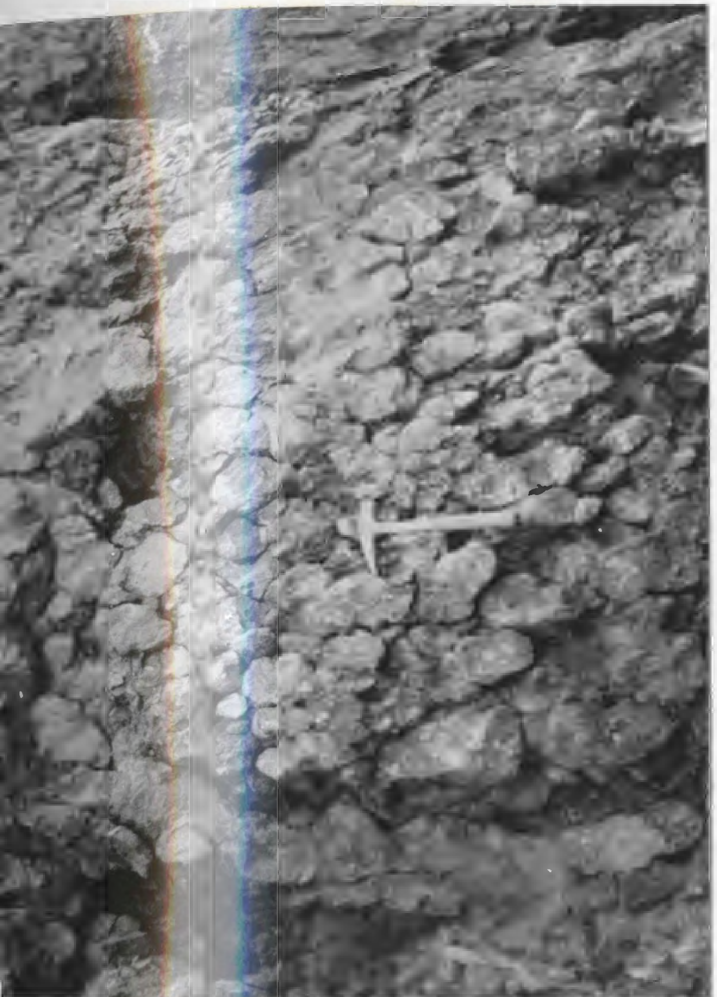


Plate 48: Gypsum laminites of the Codroy Road Formation with local structure resembling flat algal mat and containing small, displacive gypsum nodules, Fischells Brook.

Plate 49: Large, white gypsum nodule and local layers of enterolithically folded laminae in gypsum laminite of the Codroy Road Formation, Fischells Brook.



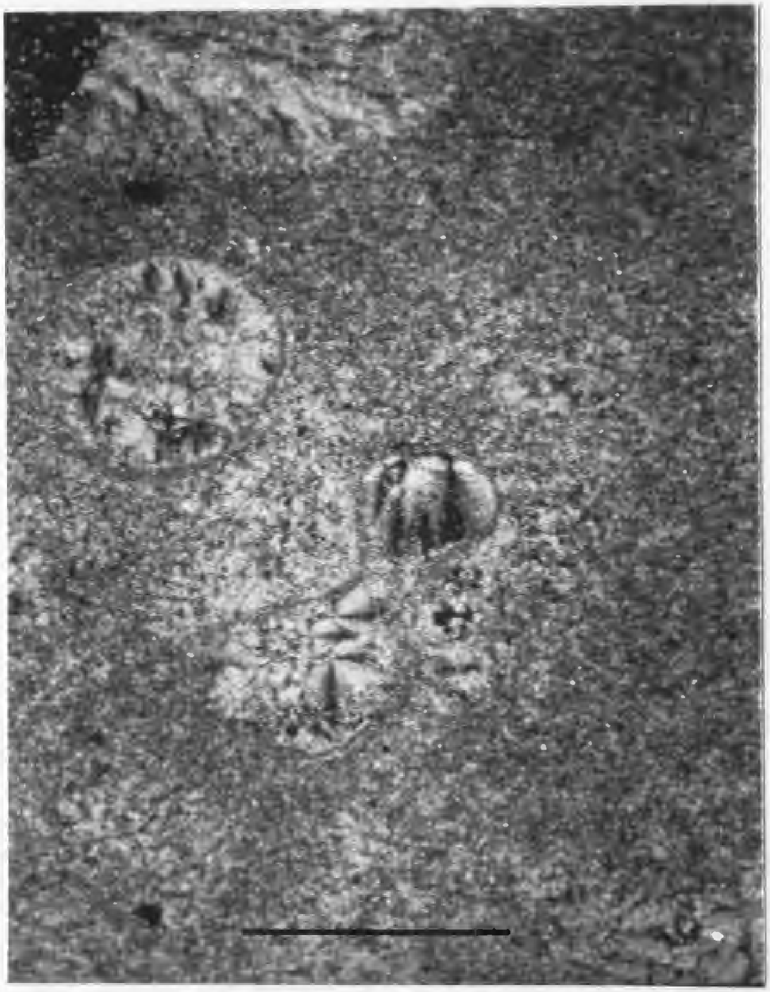


Plate 50: The top of the Black Point limestone, Codroy Road Formation, Black Point, Codroy coast. The bedding plane is composed of algal heads of black dolomite.

Plate 51: Photomicrograph of dolomite microspar from the Black Point limestone, Codroy Road Formation. The microspar contains worm tubes that are filled by brown, radial-fibrous cement which also appears to affect matrix.

Bar-1mm.

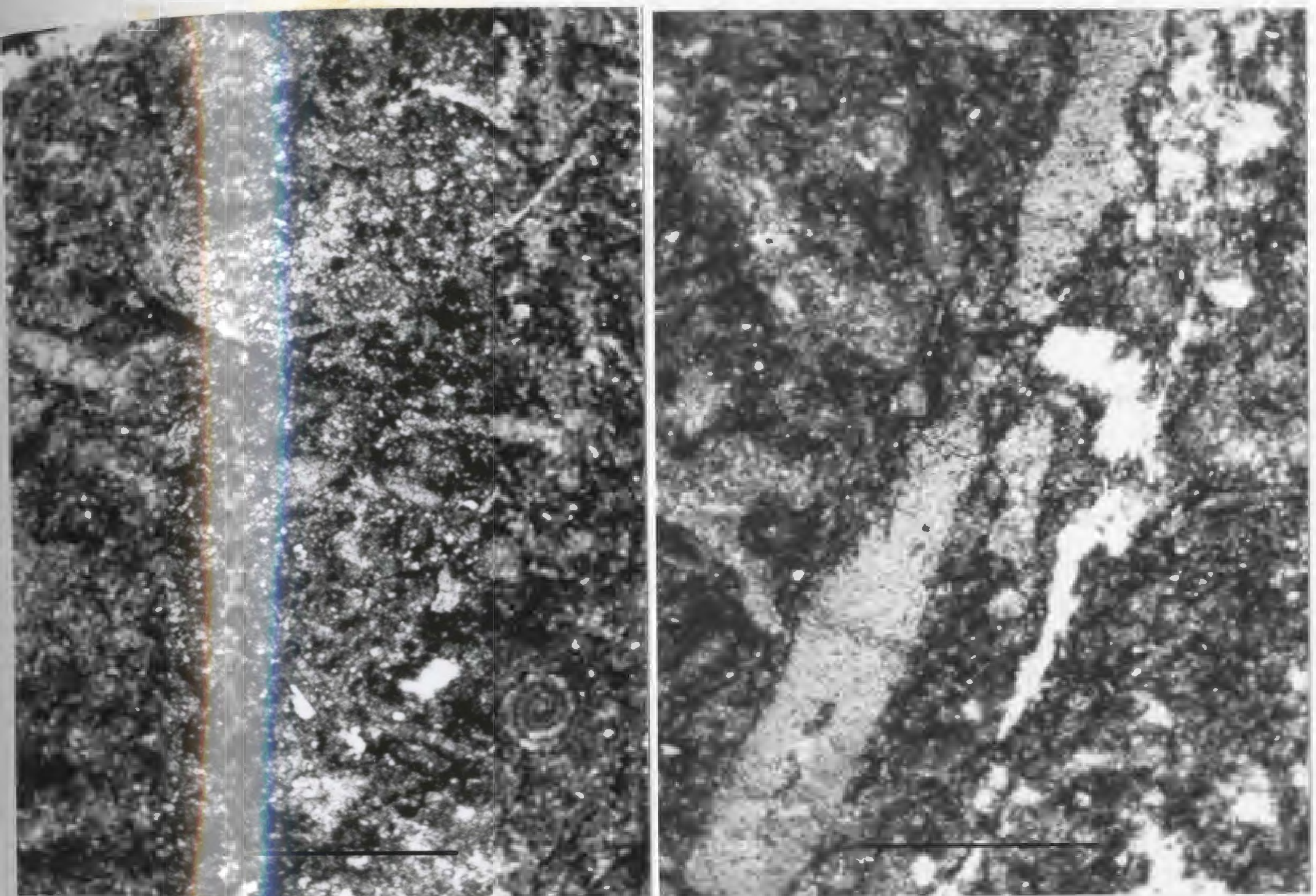
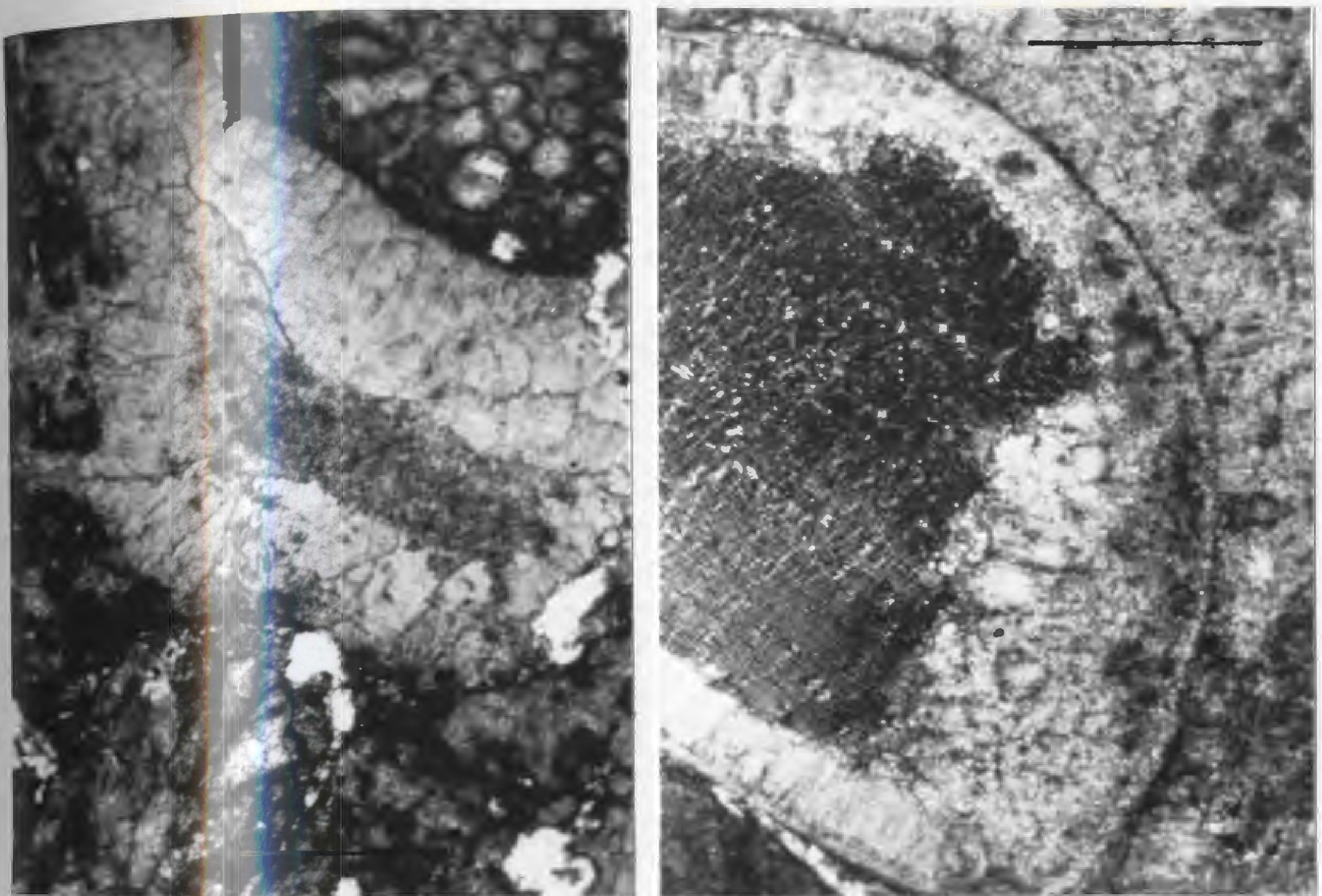


Plate 52 and 53: Photomicrographs of black argillaceous, fossiliferous dolomite from a carbonate bed from the Codroy Road Formation in the "round valley," Codroy lowlands. Most skeletal fragments are replaced by clear microspar although coiled foraminifera Cornuspira (Plate 52) and crinoid ossicles (Plate 53) are readily visible.

Bar-1mm.

Plate 54: Internally structureless, stromatolite heads, (Thrombolites) overlying dark gray calcareous mudstones below skeletal bioherm of the Cormorant limestone, Codroy Road Formation, near Ship Cove.



Plates 55 and 56: Photomicrographs of the outer zone of the North Branch bioherm, Codroy Road Formation. Brown-colored fibreous cement fills reef spaces between bryozoa and brachiopod shells, and lines the inner walls of brachiopod shells (Plates 55 and 56). Pores in bryozoa were filled by a later clear spar cement which also overlays the fibrous cement in brachiopod shells and fills remaining open spaces in the reef. Mottled lime mudstone is also seen locally.

Bar-1mm.

CORMORANT LIMESTONE	FISCHELLS LIMESTONE	CRABBES LIMESTONE	
Compiled from Hayes and Johnson (1938); Bell (1948); and Fong (pers. comm., 1976).	Bell (1948); Fong (pers. comm., 1976)	Grace McGlynn (1980 , pers. comm.); Mamet (1968)	
Brachiopoda *Beecheria davidsoni* *Beecheria latum* *Beecheria milviformus* *Camaroteochia* sp. *Composita* sp. *Diaphragmus tenuicostiformis* *Hartella* sp. nova. *Ovatia lyelli* *Pugnax dawsonianus* *Pugnax* sp. Pelecypods *Aviculopecten lyelli* *Leptodesma dawsoni* Gastropoda *Bulimorpha* sp. indet. Cephalopods *Michelinoceras* sp. Corals *Paraconularia planicostata* Dawson Ectoprocta (Bryozoa) *Batostomella abrupta* *Batostomella exilis* Age: Subzone B	Brachiopoda *Beecheria latum* *Beecheria* sp. *Composita windsorensis* *Diaphragmus tenuicostiformis* *Ovatia lyelli* Pelecypods *Aviculopecten lyelli* *Aviculopecten lyelliformis* *Edmondia rudis* *Grammatodon dawsoni* *Leptodesma dawsoni* *Schizodus* sp. Gastropoda *Naticopsis howi* Age: Subzone B	Brachiopoda *Beecheria* sp. *Camaroteochia acadiensis* *Diaphragmus avonensis* *Ovatia lyelli* *Pugnoides* sp. (Bell) Pelecypods *Sanguinolites niobe* *Schizodus richardsoni* *Schizodus cuneus* Gastropoda *Aclisina acutula* *Bucanopis beedii* *Straparollus minutus* Age: Subzone B or C	Foraminifera, (Mamet, 1968) *Archaediscus* sp. *Archaediscus* du groupe *A. chernoussovensis* Mamet *Archaediscus* du groupe *A. krestovnikovi* Rauzer-Chernoussova *Archaediscus krestovnikovi* Rauzer-Chernoussova *Archaediscus* du groupe *A. moelleri* Rauzer-Chernoussova *Biseriammina* sp. *Brunsia* sp. *Calcisphaera laevis* Williamson *Calcisphaera pachysphaerica* (Pronina) *Climacammina* sp. *Climacammina mississipiana* Conkin *Climacammina* du groupe *C. prisca* Lipina *Climacammina* du groupe *C. simplex* Brady *Cornuspira* sp. *Diplosphaera* sp. *Earlandia clavatula* (Howchin) *Earlandia vulgaris* (Rauzer-Chernoussova et Reitlinger) *Earlandinita* sp. *Endothyra* sp. *Endothyra* du groupe *E bowmani* Phillips *Endothyra* du groupe *E. prisca* Rauzer-Chernoussova et Reitlinger *Endothyra* du groupe *E. similis* Rauzer-Chernoussova et Reitlinger *Endothyranopsis* sp. *Endothyranopsis crassa* (Brady) *Eostaffella* sp. *Eostaffella (?) discoidea* (Girty) cf. *Hedraites* sp. *Hedraites (?) infinitesima* (Beede) *Neoarchaediscus* sp. *Palaeonubecularia* sp. *Paleaotextularia asper* (Cooper) *Palaeotextularia* du groupe *P. consobrina* Lipina *Planoarchaediscus* sp. "*Radiospaerina*" sp. cf. *Saccaminopsis* sp. *Tetrataxis* sp. *Tuberitina* sp. Age: Subzone C

Table 6: Compilation of fossil faunas from the main fossiliferous horizons in the Codroy Road Formation and the Jeffrey's Village Member of the Robinsons River Formation, in the St. George's Bay lowlands.

TABLE 7: SUMMARY OF DISTRIBUTION AND CHARACTERISTICS OF SEDIMENTARY LITHOFACIES, ROBINSONS RIVER FORMATION

LITHOFACIES	DISTRIBUTION				COLOR				GRAIN SIZE				SEDIMENTARY STRUCTURES + ORGANIC REMAINS															
	JV	H	M	OB	JV	H	M	OB	JV	H	M	OB	Sc	XB	PS/L +pl–	X L	C RD	MASS	CB	DEF	MC	EV MD	PEB	INT CL	PL RT	PL DEB	BIOT	FOSS
A. SILTSTONE	C-A	C	C-A	R	Rd Gn	Rd	Rd Gy Gn	Rd	-	-	-	-	R	R	R C	C	R	A	-	R	C	R-U	-	-	U	-	R-C	-
B. FINE SANDSTONE	C	R	C	-	Rd Gy	Rd	Gy Rd	-	C slt-F ss	VF ss	C slt -F ss	-	U-C	R	C C	C	C	R	-	C	C	-	-	U	U	U	U	-
C. PLANAR-STRATIFIED SANDSTONE	C	R	A	-	Rd Gy	Rd	Gy Rd	-	VF-F ss	VF-M ss	F-VF ss	-	U-C	U	A - C A	U	C	-	-	U	-	-	R	R	U	C	U	-
D. THICK, GRADED AND UNGRADED SANDSTONE	C U	A R	C R	-	Rd Gn-Gy	Rd Gy Ye	Gy Rd	-	VF-C ss	VC M ss	M-VF C/M -M/F ss	-	A	C-A	C U	C	U	-	R	U-C	-	-	U	U-C	U	R-C	R	-
E. PEBBLY, ARKOSIC AND MUDDY SANDSTONE	R-U	-	C	A	Br-Rd	-	Gy Br Rd	Rd Br Pk Wh	-	-	VC-M ss	VC-M ss	A	C	U -	U	-	C	C	U	-	-	C	U	-	R	-	-
F. CALICHE LIMESTONE NOD. CEM. MASS.	R R U	C U U	C C C	- -	Gy	Gy Pur	Gy	-	-	-	-	-	-	-	- -	-	-	-	-	-	-	R	-	-	R	-	-	-
G. INTRAFORM-ATIONAL CON-GLOMERATE	-	R	R	-	-	Gy	Rd Wh	-	-	-	-	-	C	C	- -	-	-	C	C	-	-	-	R	C	-	-	-	-
H. GRAY, CARBON-ACEOUS AND MICACEOUS MUD-STONE-SILTSTONE	-	-	C	R	-	-	Gy Bk	Gy Bk	-		C slt -M ss	C slt -M ss	R	-	R -	C	-	C	-	R	R	-	-	-	R	C	R	-
I. INTERCALATED CALCAREOUS MUD-STONE-CARBONATE-MICACEOUS SAND-STONE	-	-	C	-	-	-	Gy Bk	-	-	-	C slt -M ss		U	U	C -	C	-	C	-	U	R	-	-	-	-	C	U-C	U
J. PEBBLY MUDSTONE	R	-	-	R	Rd	-	Gy	-	-		-	-	R	-	- -	-	-	C	C	-	-	-	C	R	-	-	C	-
K. RED CALCAREOUS SHALY SILTSTONE	C	-	U	-	Rd	-	Rd	-		-	-	-	R	-	U -	U	-	-	-	-	C	R	-	-	U	-	-	-
L. BEDDED GRAY MUDSTONE-SILT-STONE/SANDSTONE -CARBONATE	R	R	R-C	-	-	Gy Wh	Gy Rd	-		C slt -VF ss	C slt -VF ss		U	R	U U	C	-	-	-	U	U	U	-	R	-	U	C	U
M. GRAY SHALE - SILTSTONE/ SANDSTONE	U	-	U	-	Gy	-	Gy	-	C slt-F ss	-	C slt -M ss	-	U-C	U	C C	C	-	-	-	U	U	U	-	-	-	U-C	C	C
N. VARICOLORED MUDSTONE	C	- -	-	-	Bk, Bl-gy, Gn -gy, Gn, Rd	-	-	-	-	-	-				- C	R	-	C	-	C	U	U-C	-	-	-	-	-	-
O. HALITE-BEARING SILTSTONE-SANDSTONE	C	-	-	-	Br-Rd Gy	-	-	-	C slt-VF ss	-	-	-	U-C	U	U C	C	U	C	-	U	C	C	-	R	R	-	-	-
P. GREEN-GRAY MUDSTONE-SILTSTONE	C	-	-	-	Gn-gy Gn		-	-	C slt	-	-	-	R	U	- -	C	C	C	-	U	U	U	-	-	-	-	-	-
Q. CROSSBEDDED SANDSTONE	C	-	-	-	Gn-gy	-	-	-	VF ss-F ss	-	-	-	A	A	C -	C	C	-	-	U	U	-	U	C	-	U	-	-
R. MARINE CARBONATE	C	-	-	-	Gy Rd	-	-	-	-	-	-	-	-	-	R -	U	-	C	-	-	U	U	-	-	-	R	C-U	A-R
S. EVAPORITE	U	-	-	-	Wh		-	-		-	-	-	-	-	R -	-	-	-	-	-	-	-	-	-	-	-	-	-

KEY

R = Rare, U = Uncommon, C = Common, A = Abundant; JV, H, M, OB = Member Initials; Rd = red, Gy = gray, Gn = Green, Gn-gy = green-gray, Br = brown, Bk = black, Pk = pink, Pur = purple, Wh = white, Ye = yellow; C slt = Coarse siltstone, VF, F, M, C, VC, ss = sandstone grain size; Sc = scour, XB = crossbeds, PS/L = planar stratification/lamination ± parting lineation (pl), XL = Cross lamination, CRD = climbing ripple-drift, Mass = massive, CB = Crude bedding, DEF = deformed bedding, MC = mudcracks, PL RT = plant rootlets, BIOT = bioturbation, CALICHE LIMESTONE; NOD = Nodular, CEM = cemented bed, MASS = massive and laminar, FOSS = fossils, PL DEB = plant debris

Plate 57: Thick red siltstone unit separating two lithofacies D sandstones in Highlands Member, Robinsons River Formation. Grooves are carried on the base of the upper sandstone and small caliche nodules occur at two levels in the siltstone. Measuring stick 1 m long.

Plate 58: Thick red siltstones intercalated with sheet sandstones of lithofacies B, Jeffrey's Village Member, Robinsons River Formation, Jeffrey's coastal section.

Plate 59: Sheets and lenses of fine sandstone (lithofacies B) interbedded with lithofacies A siltstones in Jeffrey's Village Member, Robinsons River Formation, Jeffrey's coastal section.

Plate 60: Fine sandstones of lithofacies B, Jeffrey's Village Member, Robinsons River Formation, north bank of Robinsons River near route 63 road bridge. Bed is composed mostly of climbing ripple-drift. Sedimentary structures locally deformed by soft-sediment deformation to form structureless sandstone in the middle of the bed. The sandstone bed is intercalated with coarsely interlaminated siltstones and sandstones.

Plate 63: Multistory channel sandstones, lithofacies D, Jeffrey's Village Member, Robinsons River Formation, Jeffrey's coastal section. Scour bases are overlain by intraclast-rich sandstones and then crossbedded sandstones in the channel sandstones. A coarsely laminated red siltstone unit intervenes between two of the sandstones.

Plate 64: Thick sandstone with pebble layers and large scale trough crossbedding which is deformed by large scale convolution. Fischells Brook, below JVL-2 limestone of the Jeffrey's Village Member.

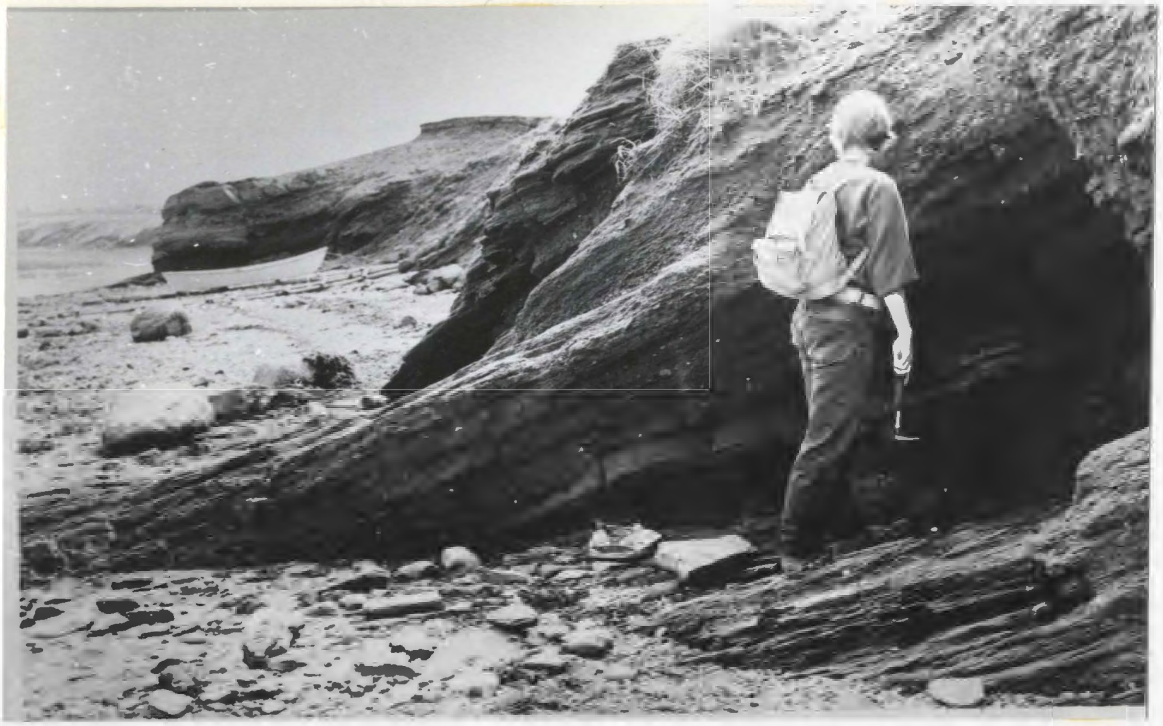


Plate 65: Conglomerate with crude stratification that cuts into crudely stratified, pebbly sandstone. Jeffrey's Village Member, Robinsons River Formation, Flat Bay section.

Plate 66: Large, trough crossbedding in arkosic sandstones of the Overfall Brook Member, Robinsons River Formation, east bank of Grand Codroy River, north of Overfall Brook.

TABLE 8: Pebble lithologies recorded in members of Robinsons River Formation

Jeffrey's Village Member

White quartz
White and pink quartzite
Red aphanitic rhyolite
Red porphyritic rhyolite
Ignimbrite
Black chert
Red jasper
Green amphibolite gneiss
Intraclasts of silt

from near Crabbes Head

FB-I

White and black quartzite
Red sandstone (Camb)
Foliated quartzite
Dolostone
Gray limestone (some mottled)
Chert
Red and gray granite
Granite gneiss
Quartz-mica schist
Green phyllite
Gabbro and ultramafic

FB-2

White quartz
White granite-gneiss
Pink foliated granite
Coarse, quartz-feldspar granite
Pink feldspar
Green quartzitic phyllite
Chlorite schist
Gray sandstone

FB-3

White quartz
Quartz-mica schist
Chlorite schist
Gray and green sandstone
Pink granite
Granite gneiss
Pink feldspar
Brecciated granite
Brown, aphanitic silicic volcanic
Brown and gray, quartzo-feldspathic porphyry and crystal tuff
Pink and yellow, spherulitic rhyolite
Red, pink and yellow, welded tuff and ignimbrite

from Flat Bay coastal section

Highlands Member

White quartz
White and pink quartzite
Red aphanitic rhyolite
Brown porphyritic rhyolite
Banded rhyolite
Black chert
Gneiss
Intraclasts of silt and caliche

from shore, north of Highlands River

Mollichignick Member

White quartz
Red mica granite
White muscovite granite
Red silicic volcanic
Porphyritic rhyolite
Granite gneiss
Green chloritic schist
Green gabbro
Green-gray diabase
Black chert

from north of South Branch River

White and rosy quartz
Pink granite
Quartz-mica-feldspar pegmatite
Muscovite-biotite-schist
Green argillite
Green chlorite schist and phyllite
Mylonitic quartz
Black lineated biotite schist
White quartz-muscovite schist
Quartz-amphibolite breccia

from 5 conglomerate beds along Grand Codroy River between South Branch and the Overfall Brook

Overfall Brook Member

White quartz
Mylonitized quartz
Shattered quartz
Quartz-mica schist
Dark gray phyllite
Pink feldspar
Red granite
Porphyritic rhyolite
Gneiss
Green fine ultramafic

from Overfall Brook type section

White and rosy quartz
Pink feldspar
Pink granite
Green, amphibolite gneiss
Black biotite schist
Green chlorite schist

from Mollichignick Brook

White quartz
Quartz-feldspar granite
Pink feldspar
Black amphibolite
Quartz-muscovite pegmatite
White schistose quartz
Black phyllite

Basal beds, Grand Codroy River north of Overfall Brook

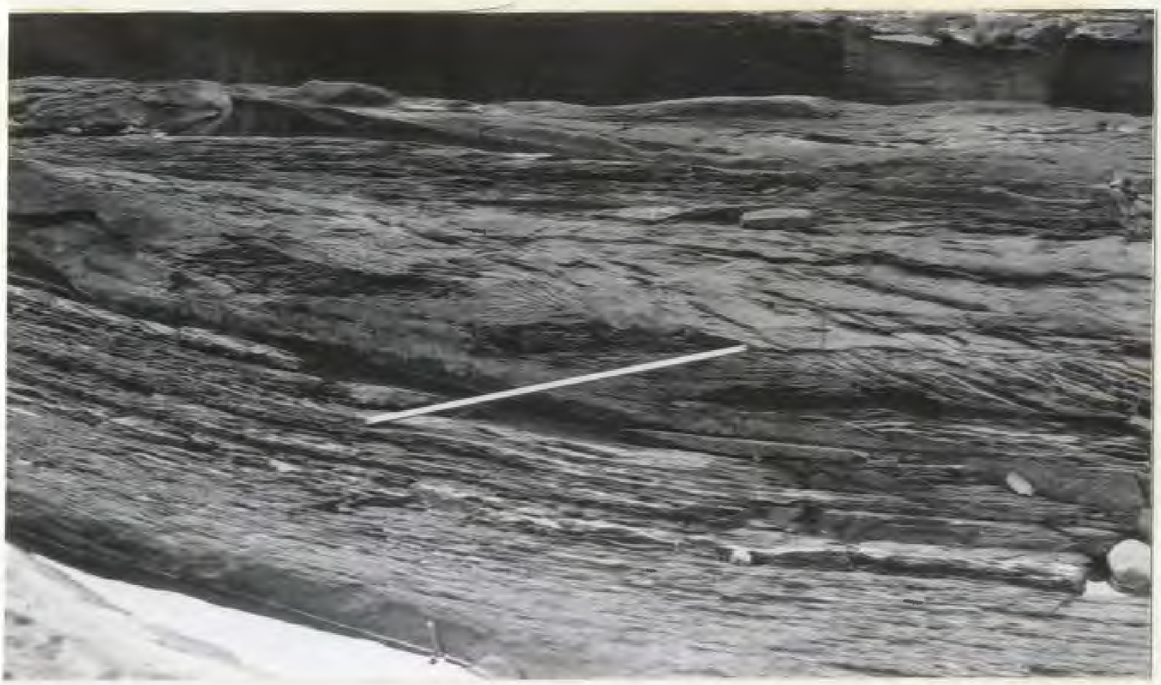


Plate 67: Trough crossbedding between planar thin stratification in red, muddy sandstones of the Overfalls Brook Member, Robinsons River Formation, at mouth of Overfall Brook.

Plate 68: Bar-shaped deposit of crossbedded gritty sandstone, associated with pebbly sandstones. Note large pebbles lying at the base of the stoss side of the bar and stratification draped over the bar. Mollichignick Member, Robinsons River Formation, Grand Codroy River.

Plate 69: Two beds of caliche in red siltstones of the Mollichignick Member of the Robinsons River Formation, south of the mouth of Stephens Brook, Grand Codroy River. Lower bed is cemented siltstone (cb), upper bed is of relatively pure, clean limestone.

Plate 70: Caliche cementing a conglomerate bed in the lower part of the Flat Bay section of the Jeffrey's Village Member, Robinsons River Formation.

Plate 71: Thick nodular caliche with laminar top and remnants of red siltstone in Mollichignick Member, Robinsons River Formation, tributary entering the north side of South Branch River.

Plate 72: Intraformational conglomerate lithofacies G, Highlands Member of Robinsons River Formation in a channel (arrow) cutting through red siltstone that contains cylindroid caliche of Plate 73. The channel eroded to the top of the underlying red sandstone unit. Thick, massive caliche (packsack) with blocky fracture capped all lithologies.

Plate 73: Vertical cylindroids or pipes, some with hollow centres (arrow) projecting down into red siltstones within the Highlands Member type section. Note basin-shaped deposits of caliche above hammer. A 15 cm siltstone layer separates the cylindroid caliche from overlying massive caliche bed shown in Plate 72.

Plate 74: Purple-gray and red caliche bed splitting a pebbly sandstone bed in two. Note depression filled by caliche at top of metre stick and large block of pebbly sandstone enclosed in the caliche immediately above arrow. Jeffrey's Village Member, Robinsons River Formation, Flat Bay section.

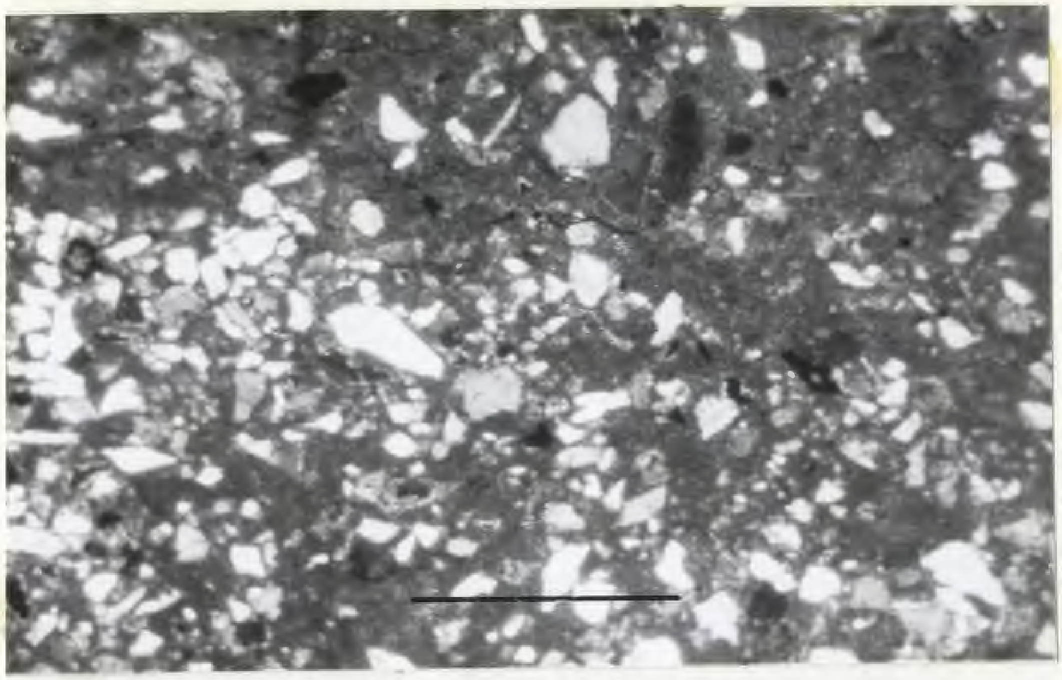


Plate 75: A photomicrograph of a cemented siltstone bed from the Mollichignick Member, showing the transition from calcareous siltstone to silty limestone at the margin of a pure carbonate nodule.

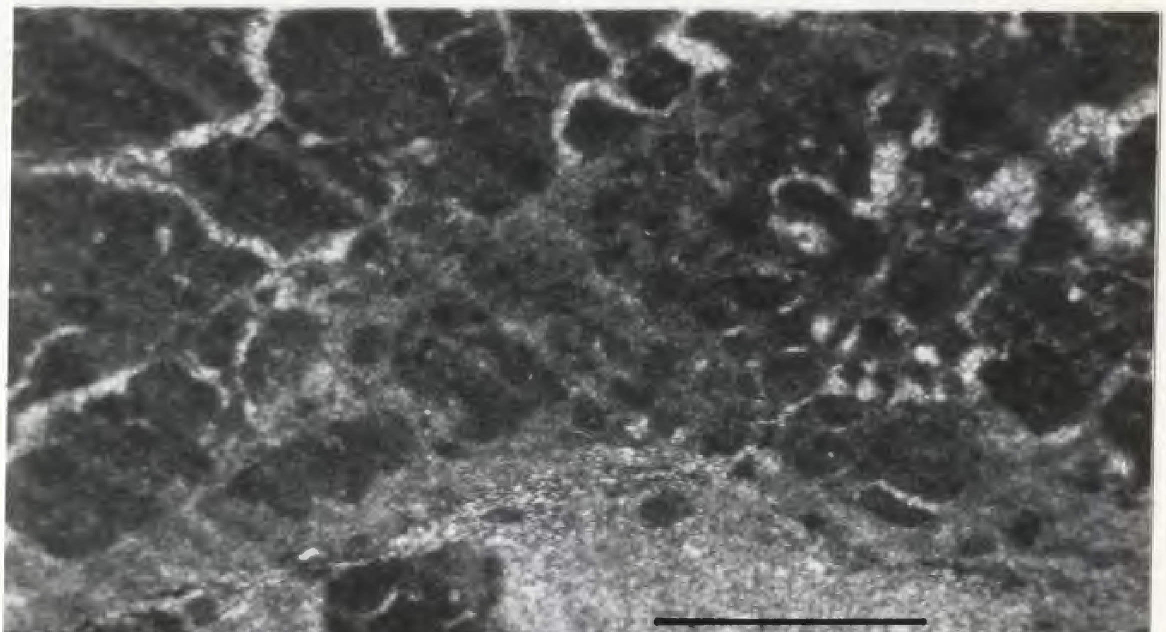


Plate 76: Photomicrograph of an old caliche, Mollichignick Member. It is composed of micronodules of dark micrite within lighter colored microspar. A shale parting is visible beneath the microspar. Dilation cracks surround and cut across the nodular micrite. They are now filled by microspar cement.

Bar-1mm.

Plate 77: Bed of siliceous caliche in the Mollichignick Member, Robinsons River Formation, Grand Codroy River. Red to brown chert occurs within generally massive, gray limestone.

Plate 78: Interbedded calcareous mudstones and carbonates of lithofacies I, Mollichignick Member. Locality as in Section A, Figure 26, upper lacustrine sequence, North Branch River.

Plate 79: Small concretionary carbonate in calcareous mudstones of lithofacies I, Mollignick Member. Locality as in Section A, Figure 26, upper lacustrine sequence.

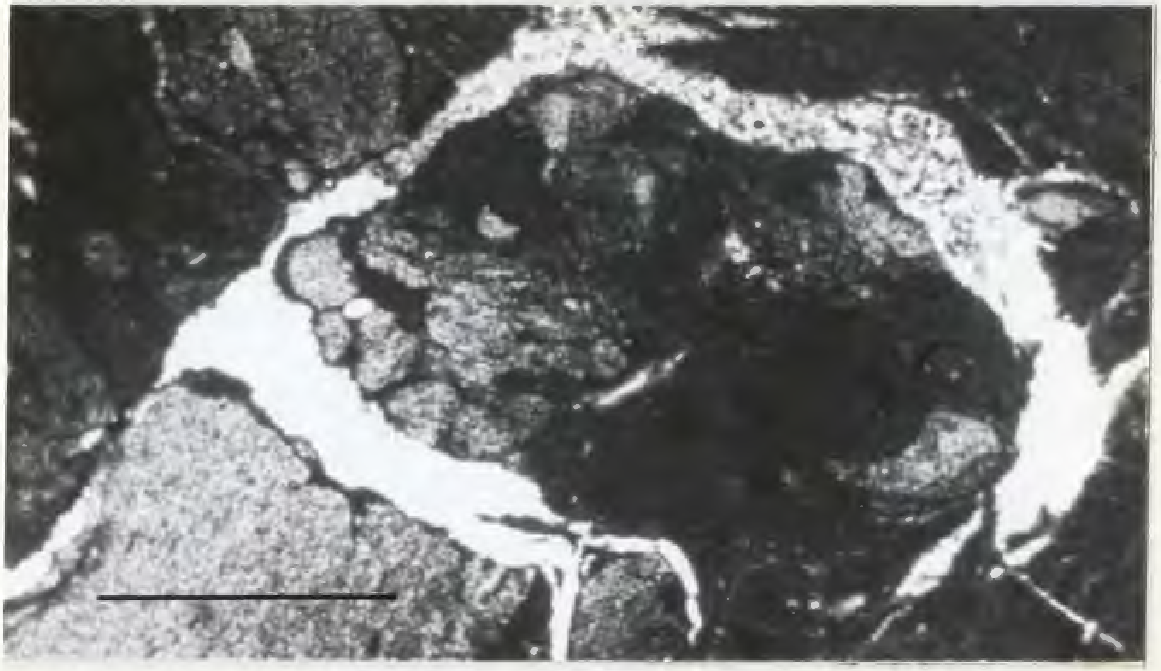


Plate 80: Photomicrograph of nodular carbonate from paludal mudstones that form part of section A of Figure 26. The carbonate is cut by curved dilation cracks filled by clear spar. Finer cracks splay off the main fracture similar to those described for paludine muds and carbonates by Freytot (1973). Bar-1mm

Plate 81: Planar, thinly stratified, micaceous, gray, very fine sandstones with local convolution and some crossbeds, lithofacies I, Mollichignick Member, Grand Codroy River, 1 km north of the village of South Branch (section A, Figure 26).

Plate 82: Red shaly siltstone of lithofacies K with beds and lumpy layers of carbonate, Flat Bay section, Jeffrey's Village Member, Robinsons River Formation.

Plate 83: General view of lithofacies L, Mollichignick Member, Robinsons River Formation, (section C, Figure 28). Carbonate beds are interbedded with micaceous sandstone and shales in foreground; thick, crossbedded sandstone (lithofacies Q) occur in the background above beds that belong to lithofacies M. Spherical solution pits in the bedded dolomitic limestones mark the sites of calcified anhydrite nodules. Southeast bank of Grand Codroy River, opposite Limestone Brook.

Plate 84: Laminated sandstones of lithofacies L, Mollichignick Member, Robinsons River Formation, location opposite Limestone Brook on the Grand Codroy River. Note scour surfaces, and local convolution. Ripple cross-laminated sandstones overlie the laminated bed.

Plate 85: Close-up of gray calcareous shaly mudstone overlain by stratified, dolomitic, skeletal packstone and wackestone seen in Plate 83. Fossil debris at base is arrowed. Calcified anhydrite nodules in the middle of the bed are also arrowed.

LEGEND for FIGURE 28

Wave ripple-marks and cross-lamination

Ripple cross-lamination and climbing ripple-drift

Current rippled sandstone

Crossbedding

Planar lamination

Convolution

Wavy bedding

Lenticular bedding

Flaser bedding

Massive

Shale bed or parting

Mudcracks

Bioturbation

F *Fossils*

Oncolites

Limestone lumps

Oolites

Vugs

Fenestral porosity

Red Color

Gray or white color

Carbonate

Inclined, columnar stromatolite

× × *Gypsum*

Halite pseudomorph

Shale intraclasts

Plant debris

Plant rootlets

→ *Current direction*

Crest of ripple mark

↔ *Parting lineation*

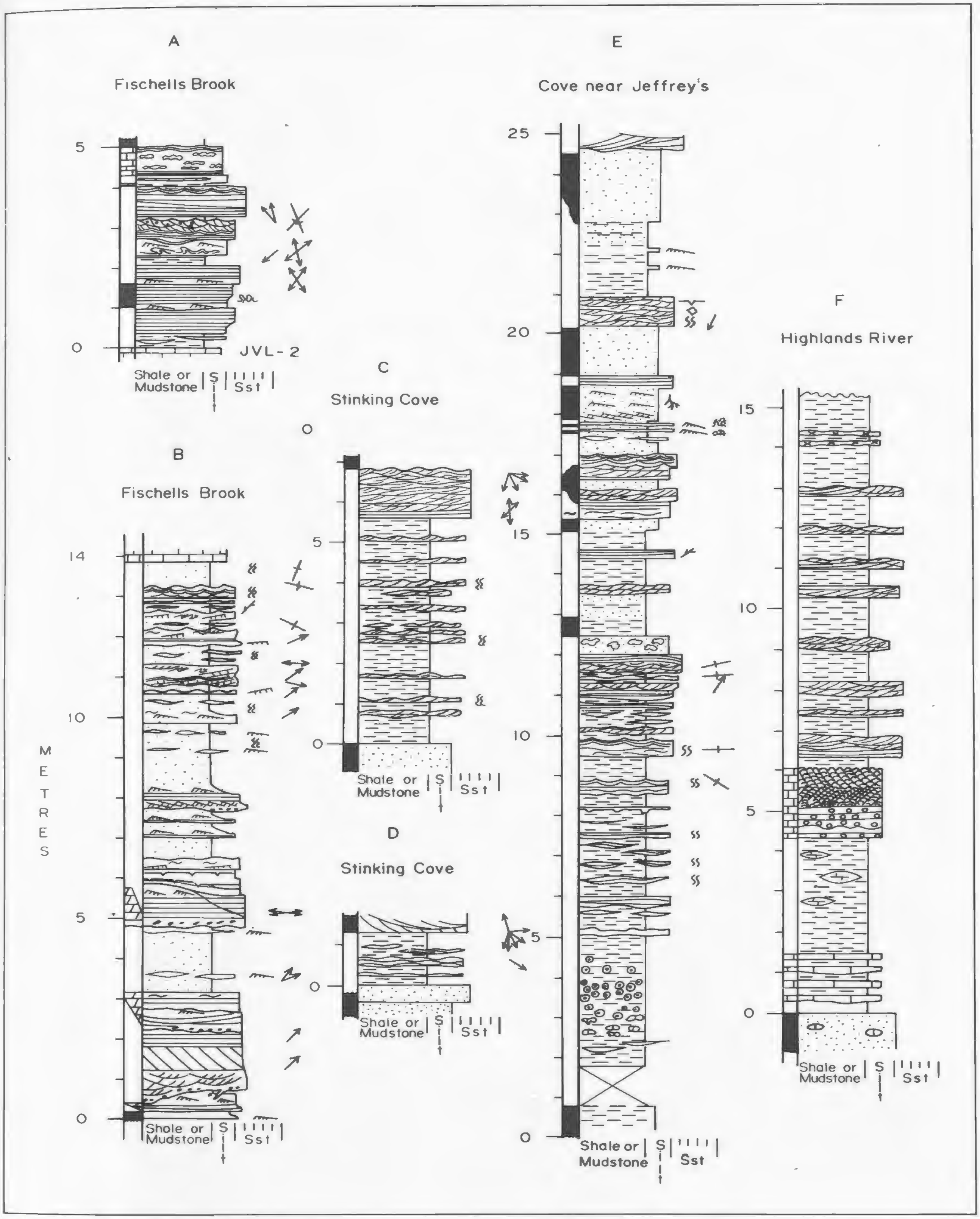


Figure 28: Detailed sedimentological sections in lithofacies M and T, St. George's Bay lowlands. Sections also include rock types from marine carbonate lithofacies and nonmarine redbeds. The location of sections A, B and E is given in Figure 20.

Plate 86: Thick sequence of lithofacies M in the Jeffrey's coastal section of the Jeffrey's Village Member, Robinsons River Formation. The section is composed of several coarsening-upward sequences of shales and sandstones. Algal oncolites and limestone lumps are found in shale near base (circle). Ripple-marked bedding planes ocur in the sandstones at the top of the section.

Plate 87: Thick sequence of gray to black shales, sandstones and some carbonates of lithofacies M, Mollichignick Member, Robinsons River Formation, Grand Codroy River (section= A2, Figure 27). Sequences that coarsen upward occur above hammer. Red shaly siltstones (lithofacies K) are below the marine beds, lower right hand corner of plate.

Plate 88: U-shaped burrows and fine tubular burrows (upper part of bed) in well sorted, laminated and bedded white quartzose sandstones of lithofacies M, Mollichignick Member, Robinsons River Formation. Grand Codroy River near Limestone Brook.

Plate 89: Thick, planar-stratified sandstone interlayered with mudcracked thin mudstone layers of lithofacies M, Jeffrey's Village Member, Robinsons River Formation below Fischells limestone, Fischells Brook. A channel is eroded into planar stratified sandstone which had been cemented by carbonate prior to erosion.

Plate 90: Varicolored mudstones of lithofacies N (at hammer) overlying ripple-marked sandstones that are interbedded with mudcracked, black shale drapes. Both beds are sandwiched between brown and red, halitic siltstones and sandstones (lithofacies O). Lower part of Jeffrey's Village Member, Robinsons River Formation, Fischells Brook, 300 m downstream from railway bridge.

Plate 91: Bedded, halite-bearing muddy siltstones of lithofacies O. Beds are dominantly structureless except for some faint lamination at base. Lower part of Jeffrey's Village Member, upstream of Fischells limestone, Fischells Brook.

Plate 92: Brown, ripple cross-laminated, very fine sandstone overlying halitic, red siltstone in sequence of lithofacies O. Laminated and ripple cross-laminated foresets of sandstone accreted laterally from tapering margin of earlier sandstone deposit. Fischells Brook, lower part of Jeffrey's Village Member upstream of Fischells limestone.

Plate 93: Thick, crossbedded, green-gray, very fine to fine grained sandstones of lithofacies Q (section B, Figure 29). South bank of Fischells Brook, in lower part of Jeffrey's Village Member, below Fischells limestone.

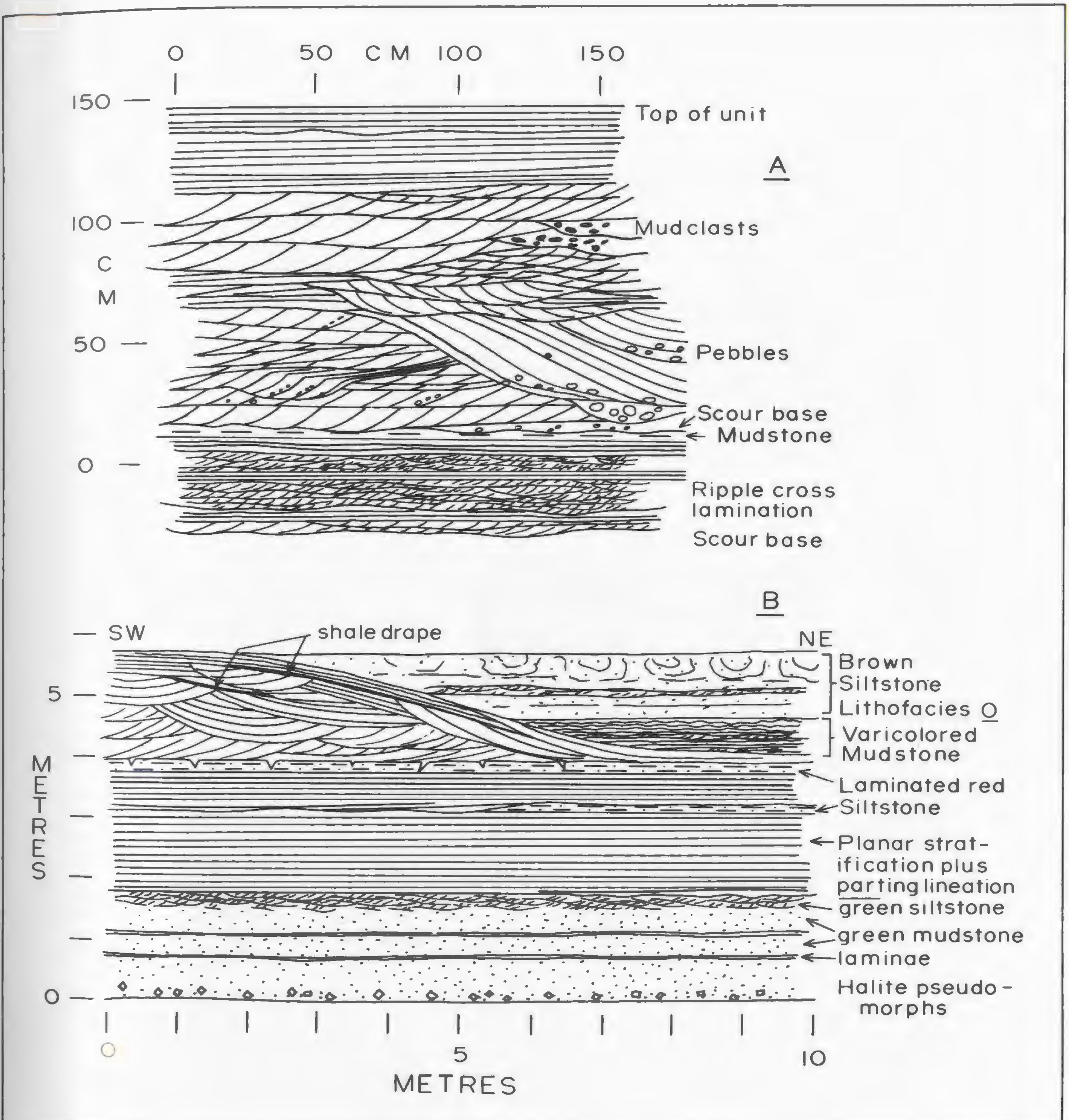


Figure 30: Notebook sketches of structures in lithofacies Q sandstones of the Jeffrey's Village Member, Fischells Brook. Sketch A is taken from a unit in the upper 10 m of section D, Figure 29, and shows the abundance of scouring and the apparent reversal of trough crossbed current direction. Sketch B is of a bar-shaped sand body (section C, Figure 29) which consists of sandstones overlying a type 1, coarsening-upward unit of green mudstone and ripple-laminated siltstone.

Plate 94: Fischells limestone, composed of dolomitic limestone beds and recessively weathered shales or mudstones, Jeffrey's Village Member, Fischells Brook.

Plate 95: The Crabbes limestone, Jeffrey's Village Member, Robinsons River Formation at Crabbes Head. It consists of well bedded, dominantly gray limestone with shale partings at base and interbedded shale and limestone upwards.

Plate 96: Large burrows, in dolomitic wackestone that is rich in skeletal remains, Fischells limestone, Jeffrey's Village Member, Fischells Brook. Burrows were filled by red siltstone.

Plate 97: Chondrites in dolomitic lime mudstone, overlain by brachiopod-rich layer in JVL-2 limestone, Fischells Brook. Upper part of Jeffrey's Village Member, Robinsons River Formation.

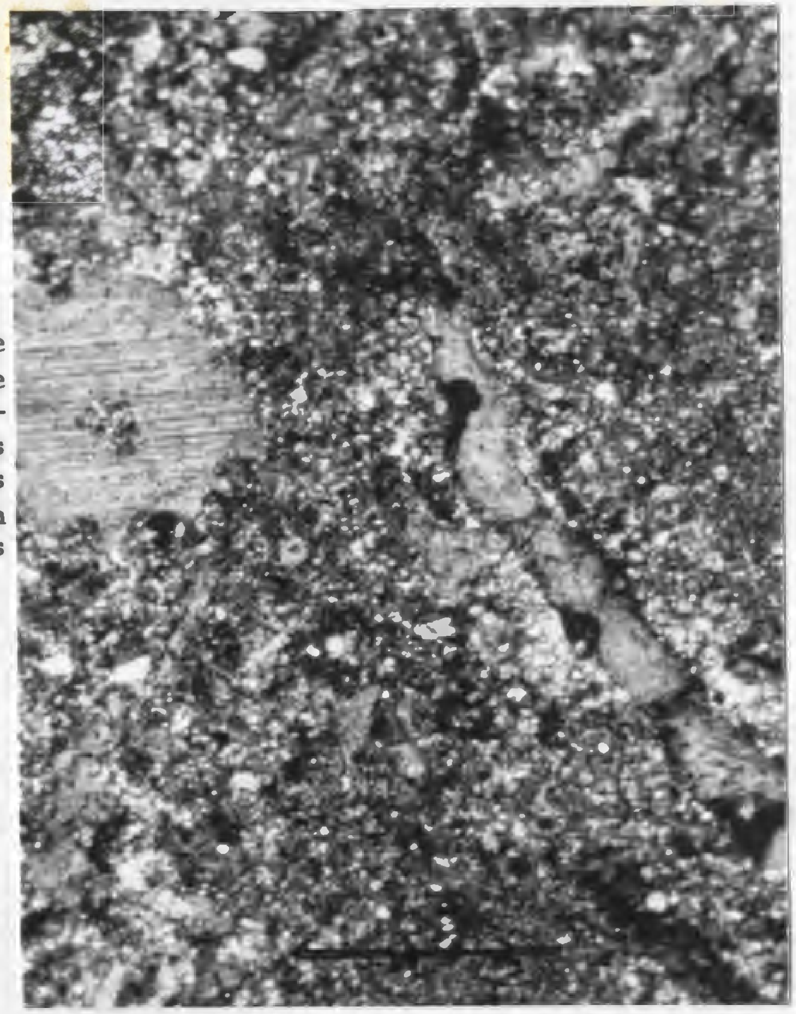


Plate 98: Crinoidal wackestone composed of complete and fragmented crinoid ossicles, Crabbes limestone, Jeffrey's Village Member, south of mouth of Crabbes River.

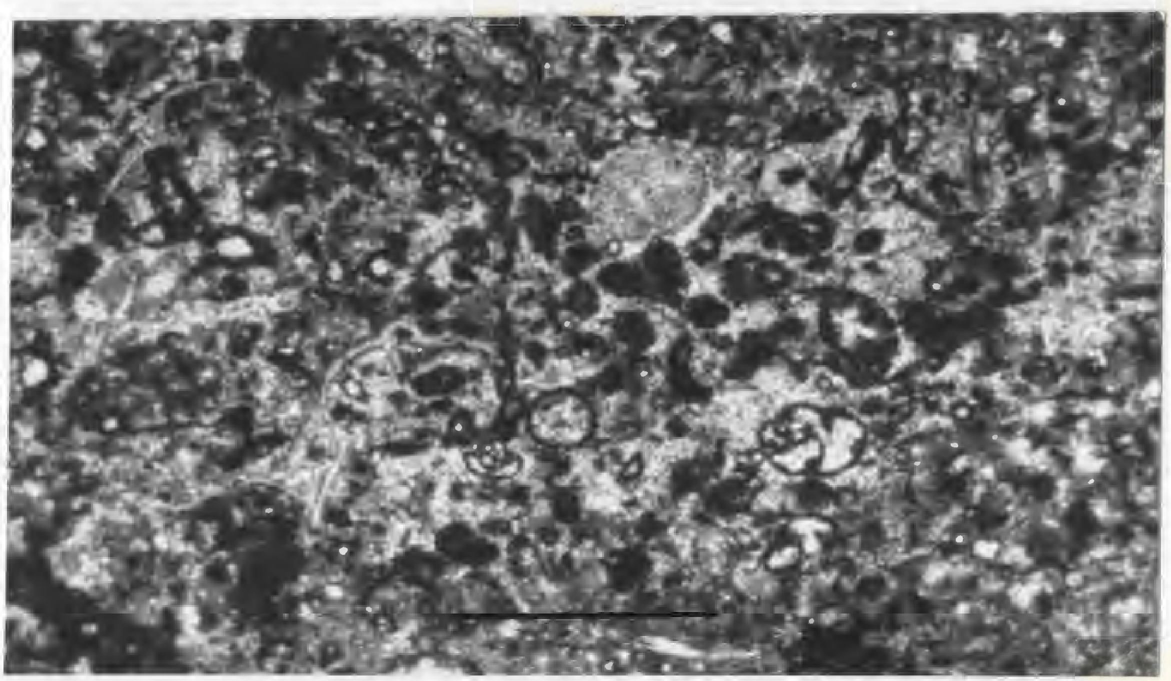
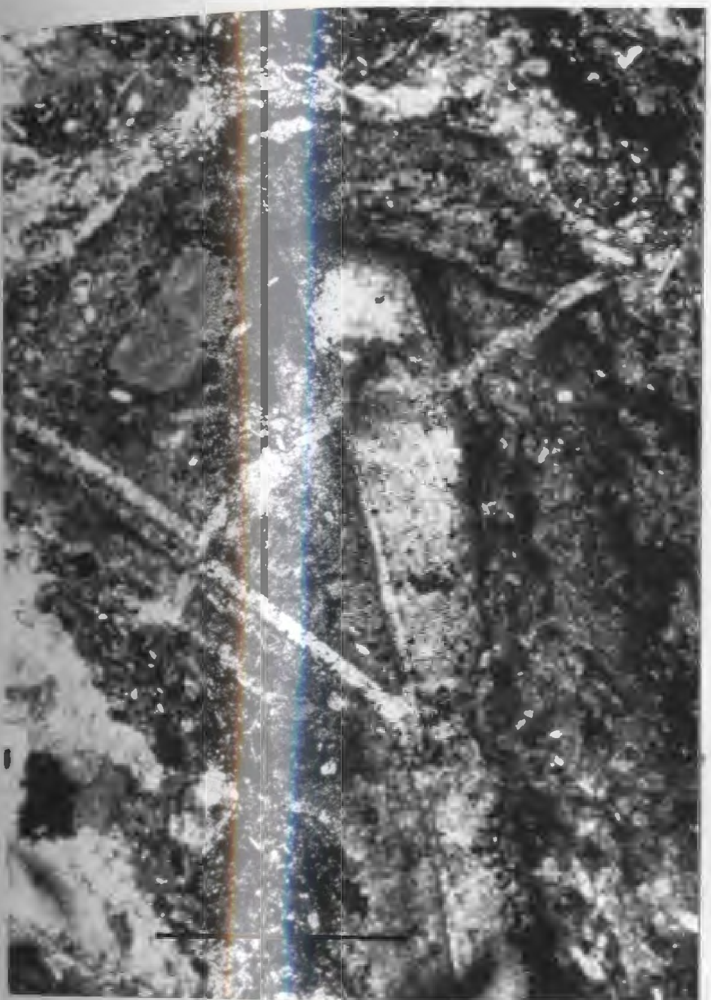


Plate 99: Skeletal-peloid packstone composed of foraminifera, crinoid ossicles, ostracods and calcispheres. Limestone in Shallop Cove, Flat Bay.

Bar-1mm.



Plates 100 to 101: Photomicrographs of areas of a goniatite shell enclosed in a carbonaceous dolomitic wackestone, the "round valley," Codroy lowlands. Algae initially bound the outer wall of the shell, sealing over fractured shell (Plate 100). Crinoid grains were enclosed by this algal coat. Within the goniatite, septa were coated by a fine, fibrous cement (Plate 101) which was also precipitated in and around whole ostracods that had entered the chambers. Chambers were later filled by blocky spar. Original shell replaced by clear neomorphic spar; structure visible (Plate 100). Authigenic quartz occurs in plate 101.

Bar-1mm.

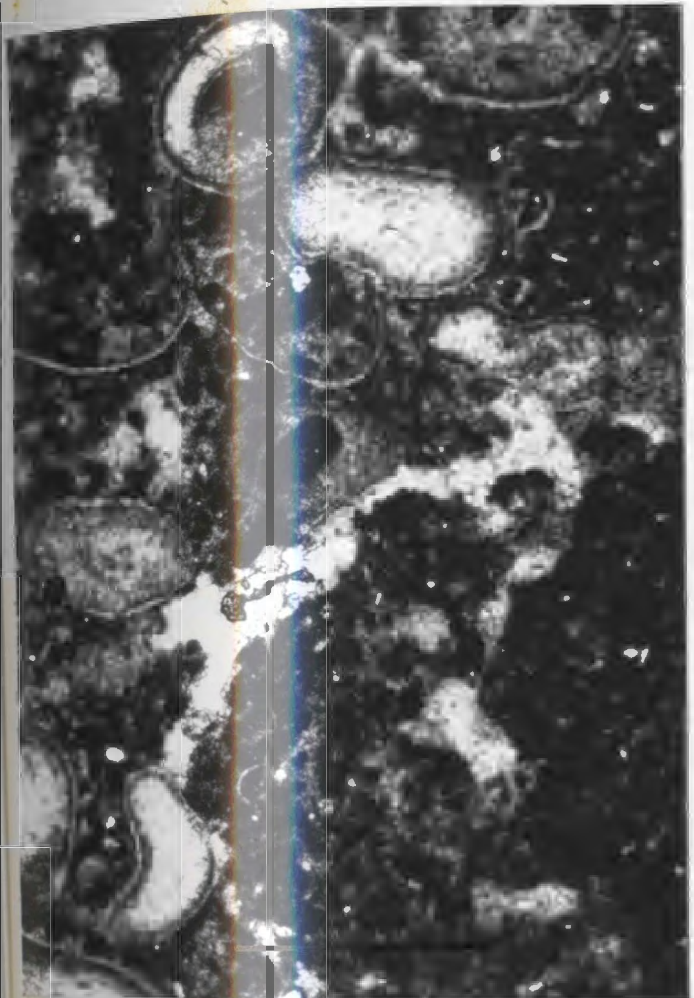
Plate 102: Heatherton limestone, Jeffrey's Village Member, Fischells Brook, composed of gray limestone and red dolomite. The upper gray limestone bed consists of calcrete-modified stromatolites. This overlies a lower, irregular gray calcrete (arrow) that caps an irregular bed of red dolomite (r).

Plate 103: Heatherton limestone, Jeffrey's Village Member at Rattling Brook, formed of large mounds built by inclined, assymmetric algal heads and columns.

Plate 104: Inclined, curved, columnar stromatolites of the Jeffrey's Village Member, in two beds that formed an algal bank above oolitic, skeletal packstones on Highlands River, near Loch Lomond. The stromatolites are overlain by gray shales and sandstones of lithofacies M.

Plate 105: Close-up of columnar stromatolites on Highlands River.

Plate 106: Lumpy, black algal carbonate of lithofacies R, Jeffrey's Village Member, Robinsons River Formation, at Rattling Brook. Bed overlies celestite and gypsum beds that are concealed below beach gravel.



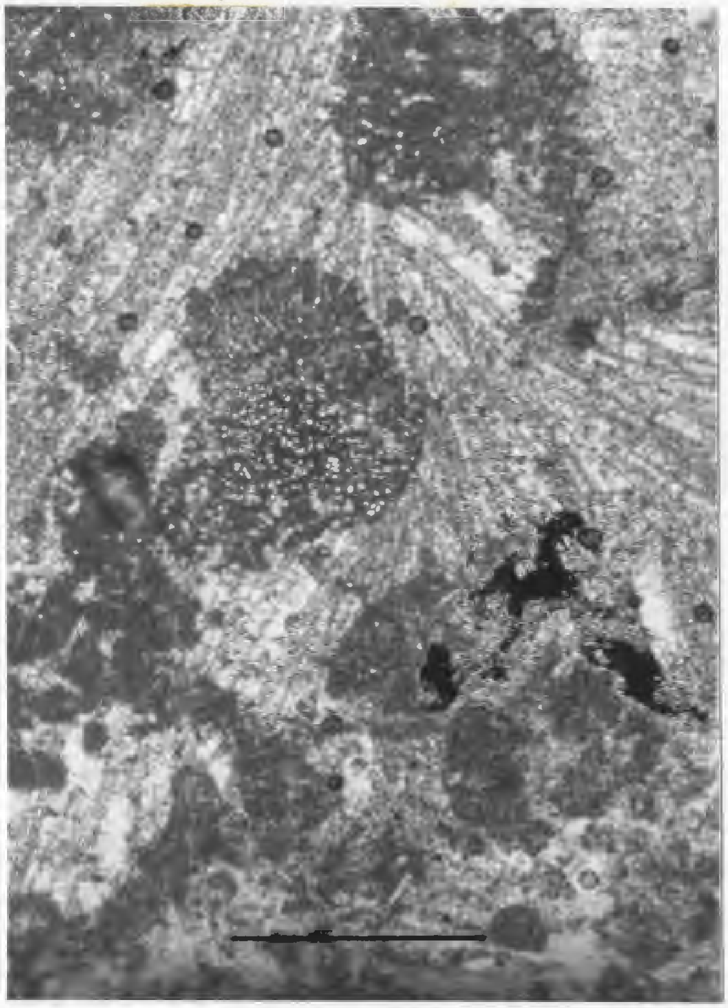
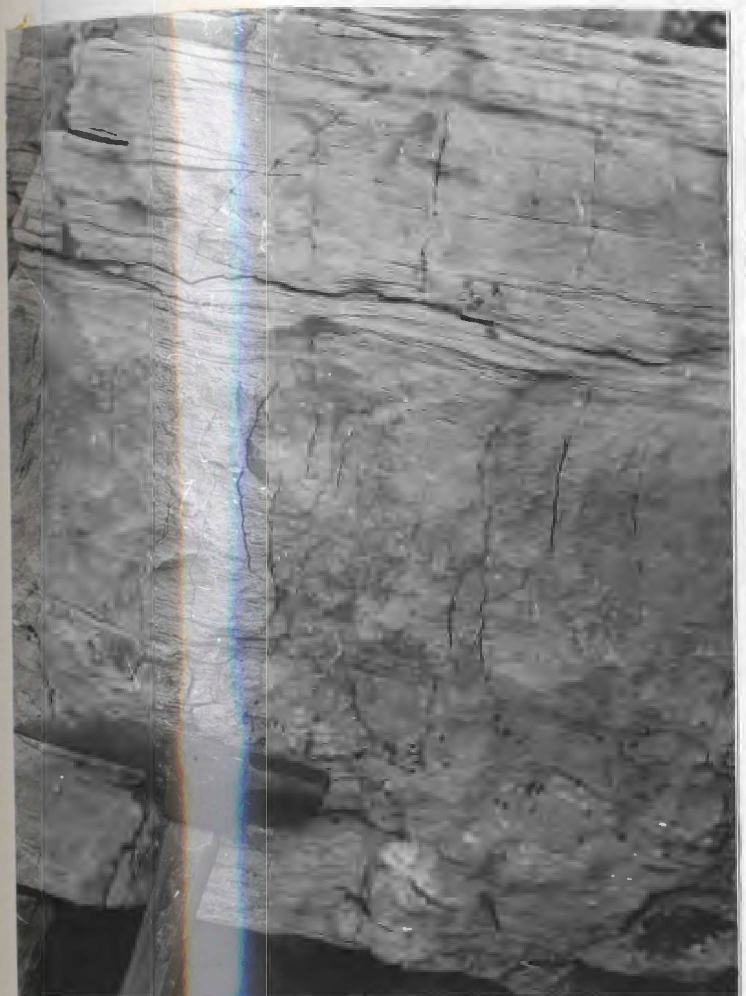


Plate 107: Photomicrography of small clots of codacian algae that form lumpy algal carbonates at Rattling Brook (Plate 106). Spaces between lumps are filled by elongate calcite crystals resembling the lath-like textures of calcitized gypsum (Shearman and Fuller, 1969).

Plate 108: Worm tubes lined by fine acicular druse and by mosaic spar, associated with dark mottled peloid packstone in the lumpy algal carbonates (Plate 106) at Rattling Brook. Base is 1 mm long.

Bar-1mm.



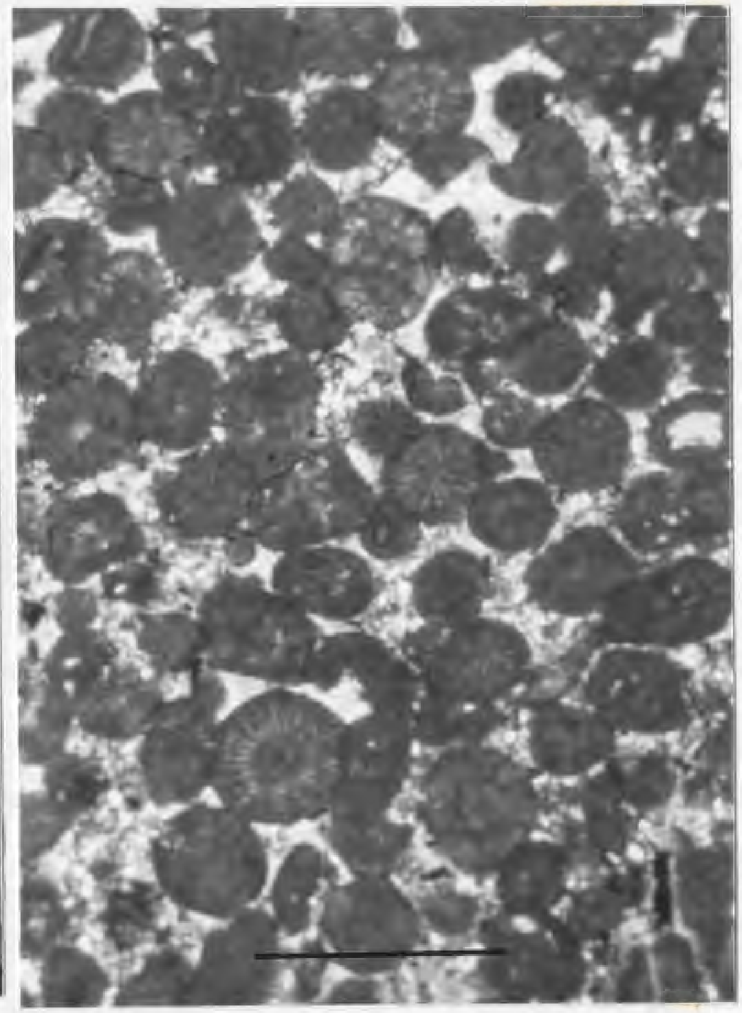


Plate 109: Oolitic limestone in carbonate unit at base of Flat Bay section, Jeffrey's Village Member, Robinsons River Formation (Figure 31). It is gray, displays lamination, wavy lamination and ripple cross-lamination, and is rich in lime intraclasts at base.

Plate 110: Oolitic grainstone from unit in Flat Bay (Plate 109) composed of radial concentric ooids cemented by sparry calcite. Grains have sutured contacts; broken ooids and several spherulites are present. Plane light.

Bar-1mm.

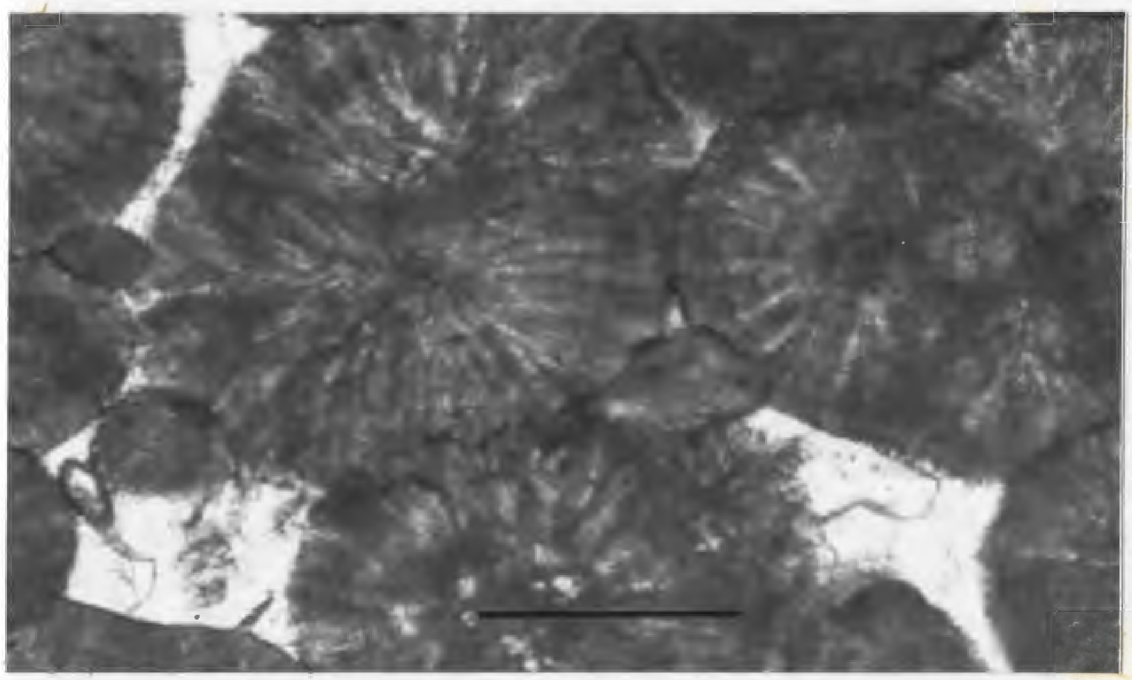


Plate 111: Close-up of radial ooids from oolitic grainstones of plate 110 showing multiple growth and fine spar-filled rays that are possibly healed microfractures. Plane light.

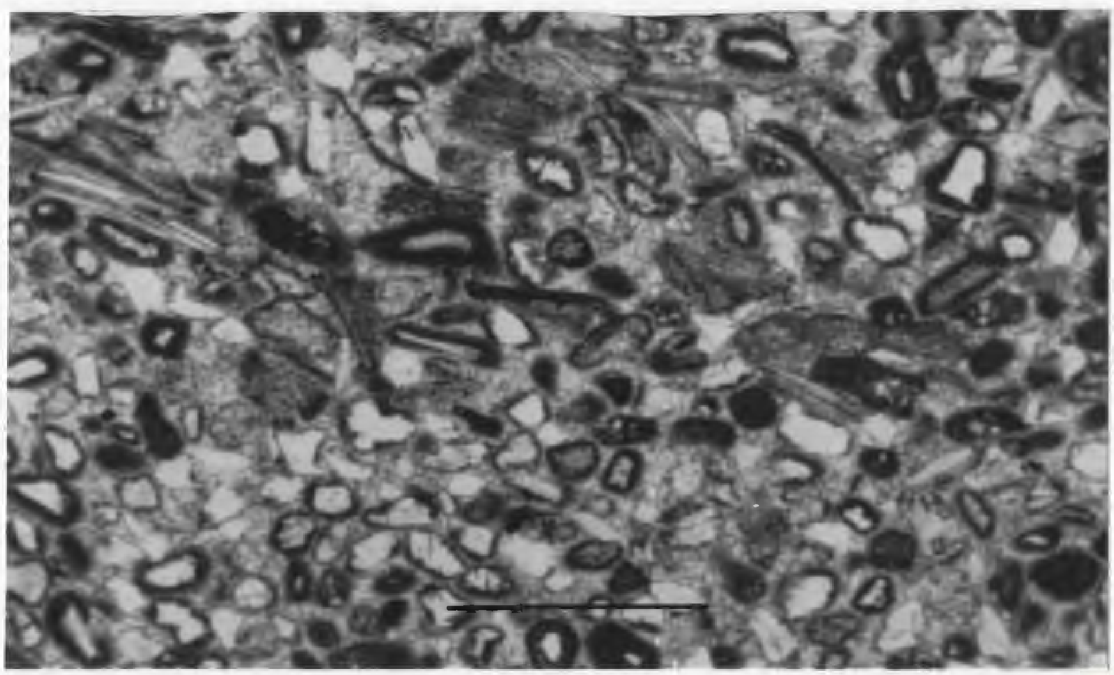


Plate 112: Coated sand grains in a calcareous, very fine sandstone from carbonate unit, Jeffrey's Village Member, at Flat Bay. Note shredded micas (arrow) and the rare ooid. Plane light.

Bar-0.25mm.

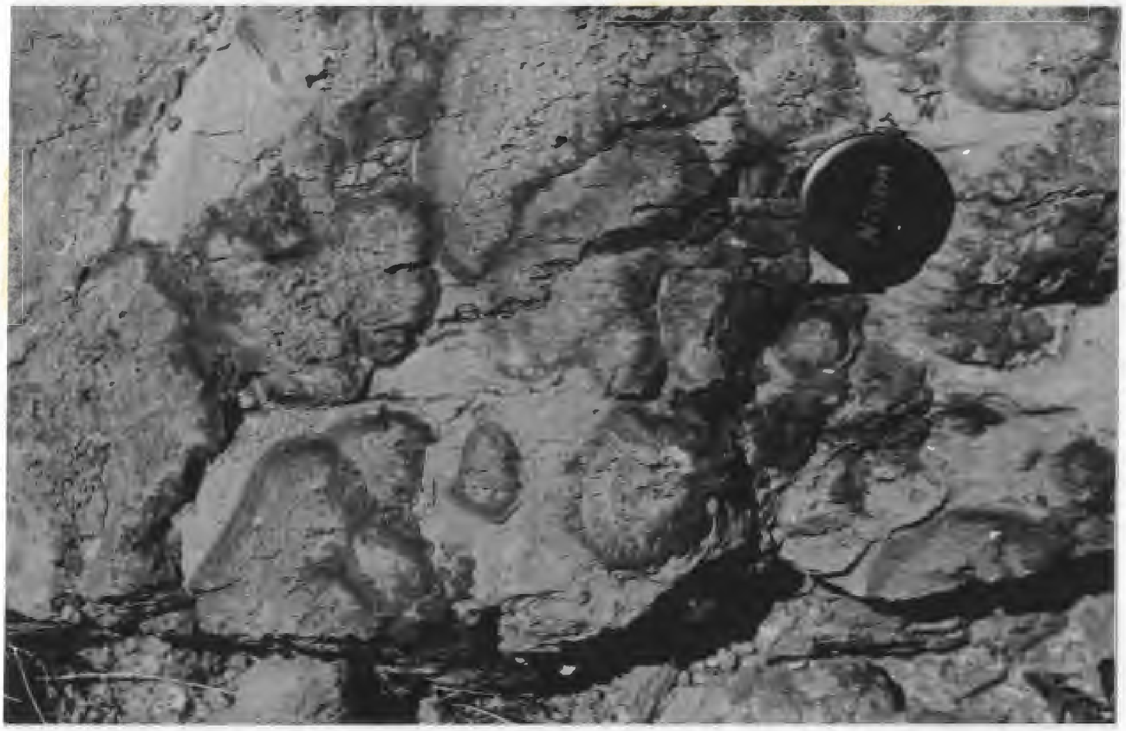
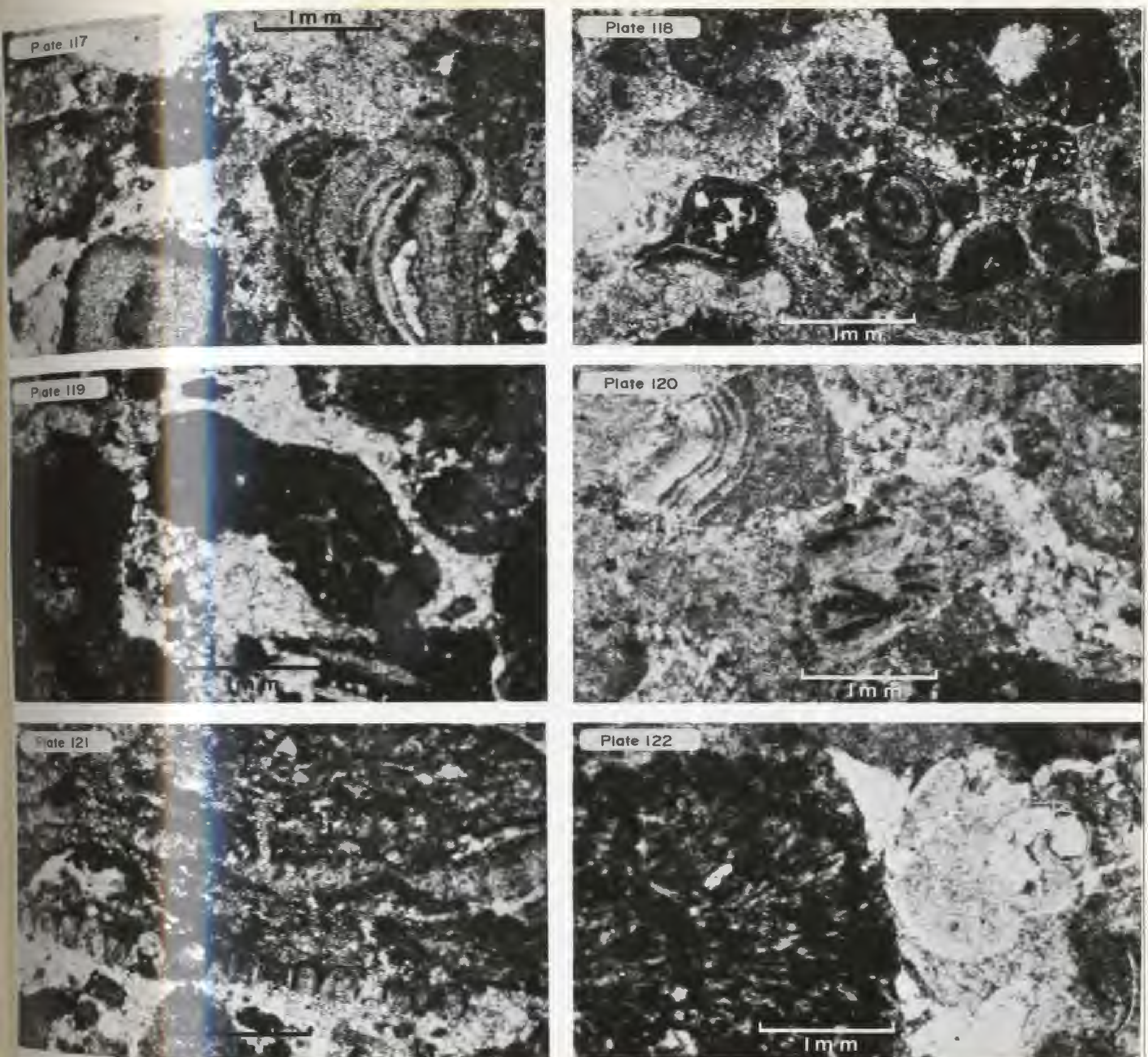


Plate 113: Red, laminar calcrete surrounding coarse fenestral core in calcrete-modified algal heads of the Heatherton limestone, Jeffrey's Village Member, at Rattling Brook. Gray carbonate infills between heads.

Plate 114: Nodular calcrete capping a fossiliferous limestone and calcareous sandstone of the Jeffrey's Village Member on the North Branch River, 3 km downstream from the main road bridge, Trans Canada Highway.

Plate 115: Interbedded limestone breccias (lithofacies R) with beds of red siltstones above main 'Codroy Breccia,' base of Jeffrey's Village Member, Robinsons River Formation, Woodville, Codroy lowlands.

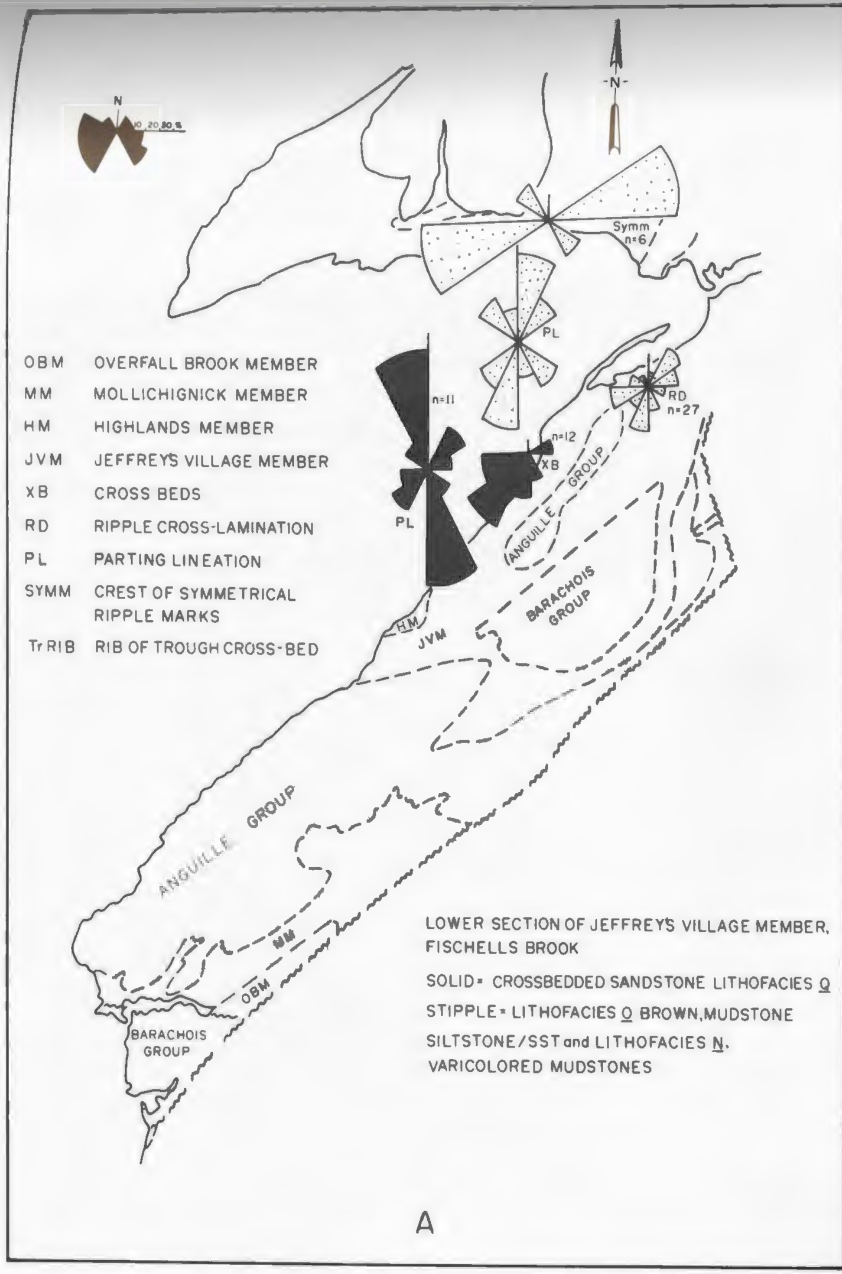
Plate 116: Close-up of limestone breccia of the 'Codroy Breccia,' Jeffrey's Village Member. Dark limestone fragments are set in a yellow, ferruginous, argillaceous carbonate matrix.

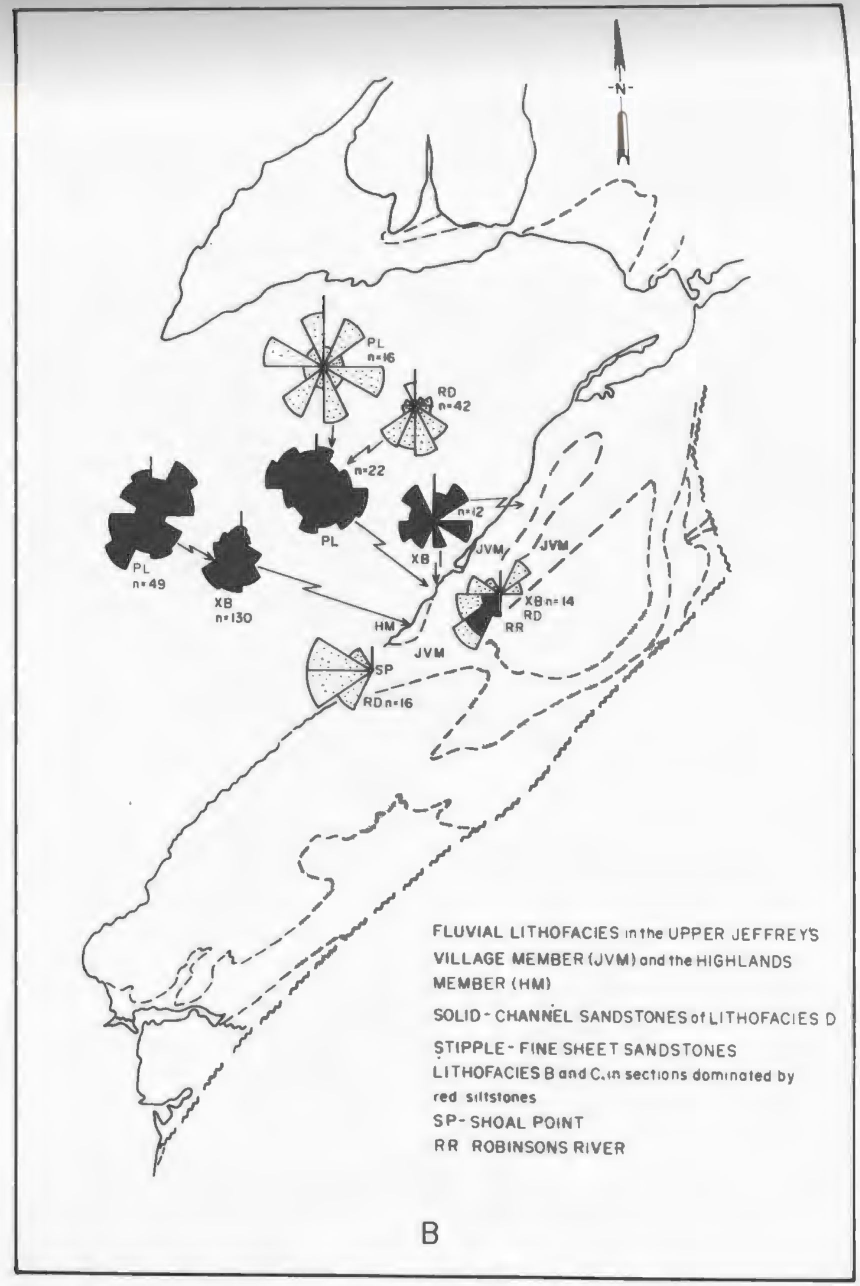


Plates 117 to 122: Photomicrographs of selected lithoclasts of the 'Codroy Breccia.' Fragments include crinoid ossicles (Plate 117), pisoliths (Plates 117 - 118), ooids and oolitic packstone (Plates 118 - 119), lithoclasts of brown fibrous carbonate replacing micrite (Plate 120), lithoclasts of radial-concentric layering (Plate 120), encrusting bryozoan and algal mat (Plate 121) and codiacean algal and worm tubes (Plate 122). Scattered quartz grains are also present, and all fragments are cemented by clear spar.

Plate 123: Layered white and red gypsum, rich in gypsum porphyroblasts. Lithofacies S, Jeffrey's Village Member, Robinsons River Formation, Rattling Brook.

Plate 124: Close-up of radiating, chevron-like structure in gypsum above that shown in Plate 123, Rattling Brook.


N
10 20 30 %
-N-
Symm
n=6
PL
n=11
n=12
XB
RD
n=27
PL
OBM OVERFALL BROOK MEMBER
MM MOLLICHIGNICK MEMBER
HM HIGHLANDS MEMBER
JVM JEFFREYS VILLAGE MEMBER
XB CROSS BEDS
RD RIPPLE CROSS-LAMINATION
PL PARTING LINEATION
SYMM CREST OF SYMMETRICAL RIPPLE MARKS
Tr RIB RIB OF TROUGH CROSS-BED
ANGUILLE GROUP
BARACHOIS GROUP
HM
JVM
ANGUILLE GROUP
MM
OBM
BARACHOIS GROUP
LOWER SECTION OF JEFFREYS VILLAGE MEMBER, FISCHELLS BROOK
SOLID = CROSSBEDDED SANDSTONE LITHOFACIES Q
STIPPLE = LITHOFACIES O BROWN, MUDSTONE SILTSTONE/SST and LITHOFACIES N. VARICOLORED MUDSTONES
A


-N-
PL
n=16
RD
n=42
n=22
PL
n=49
PL
XB
n=130
XB
n=12
JVM
JVM
HM
JVM
XB n=14
RD
RR
SP
RD n=16
FLUVIAL LITHOFACIES in the UPPER JEFFREYS VILLAGE MEMBER (JVM) and the HIGHLANDS MEMBER (HM)
SOLID - CHANNEL SANDSTONES of LITHOFACIES D
STIPPLE - FINE SHEET SANDSTONES LITHOFACIES B and C. in sections dominated by red siltstones
SP - SHOAL POINT
RR ROBINSONS RIVER
B

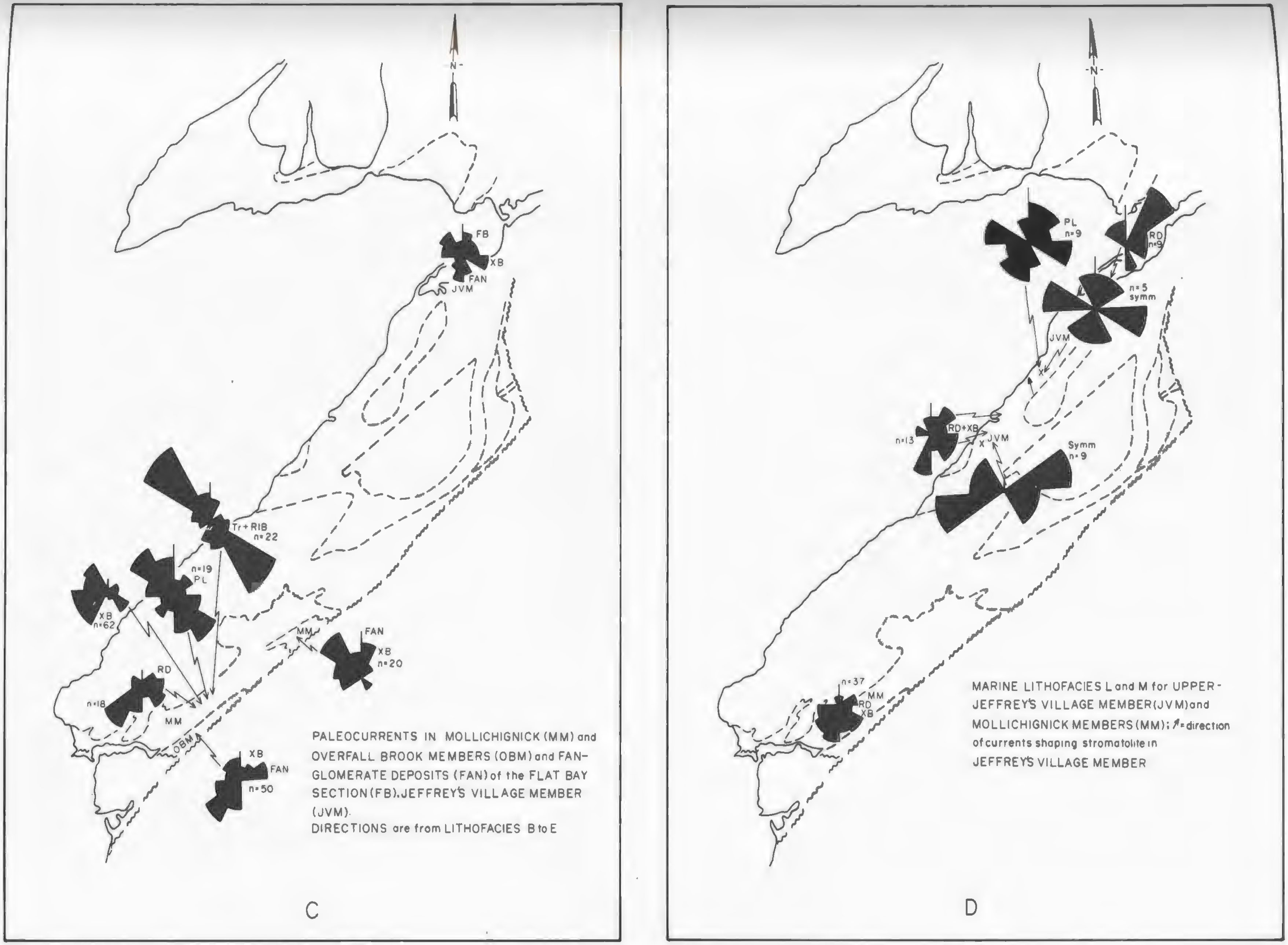


Figure 32: Paleocurrent data for different members and nonmarine and marine lithofacies of the Robinsons River Formation.

MOLLICHIGNICK MEMBERS, ROBINSONS RIVER FORMATION

MACROFOSSILS

PELECYPODS

Edmondia hartti
Leptodesma sp
Modiolus hartti
Sanguinolites parvus
Sanguinolites striatogranulatus
Schizodus cuneus
Schizodus densyi
Streblopteria sp

GASTROPODS

Bucanopsis
Bulimorpha maxneri
Murchisonia gypsea
Naticopsis howi
Platyschisma dubium
Stegocoelia compactoidea

CEPHALOPODS

Michelinoceras vindobonense ?

OSTRACODS

Glyptopleura sagae ?
Paraparchites sp.

Also noted crinoid ossicles and unidentifiable *brachiopods*

Fauna from localities on Grand Codroy River listed by Utting (1966) and samples (italics) from Mollichignick Brook identified by G. McGlynn (personal communication, 1979).

MIOSPORES

Punctatisporites planus
Auroraspora macra
Rugospora minuta
Verrucosisporites morulatus
Punctatisporites irrasus
Endosporites micromanifestus
Endosporites minutus
Anaplanisporites sp.
Lycospora noctuina var noctuina
Cyclogranisporites sp.
Crassispora trychera
Secarisporites remotus
Knoxisporites stephanephorus
Granulatisporites tuberculatus
Cyclogranisporites palaeophytus
Dictyotriletes cf. D. sagenoformis
Schopfipollenites sp.
Retusotriletes incohatus
Spelaeotriletes sp.

Flora recovered from sample collected on Grand Codroy River, 1 km northeast of Limestone Brook, identified by Utting (personal communication, 1978).

WOODY CAPE FORMATION

CAPELIN COVE / WOODY COVE

BRACHIOPODS

Capelin Cove

Ambocoelia acadica
Beecheria sp.
Buxtonia cogmagunensis
Martinia galataea
Ovatia lyelli
Pugnoides sp. (Bell)
Romingerina anna
Schellwienella kennetcookensis
Spirifer nox.

Woody Cove

Ambocoelia acadica
Beecheria sp.
Buxtonia cogmagunensis
Diaphragmus avonensis Bell
Martinia galataea
Ovatia lyelli
Romingerina anna
Spirifer nox

PELECYPODS

Capelin Cove

Aviculopecten lyelli
Cypricardella acadica
Edmondia hartti
Modiolus hartti
Sanguinolites striatogranulatus
Schizodus cuneus
Schizodus fundensis
Spathella insecta
Streblopteria debertianum
Streblopteria simplex

Woody Cove

Edmondia hartti
Leptodesma dawsoni
Leptodesma sp. (Bell)
Modiolus hartti
Sanguinolites straitogranulatus
Sanguinolites niobe
Schizodus cuneus
Schizodus fundensis
Schizodus richardsoni
Spathella insecta

GASTROPODS

Capelin Cove

Anematina cf. proutana
Bellerophon sp.
Euphemites cf. urei
Platyschisma dubium
Pseudozygopleura sp.
Stegocoelia abrupta
Stegocoelia compactoidea

Woody Cove

Aclisina acutula
Bellerophon sp.
Euphemites cf. urei
Naticopsis sp.
Platyschisma dubium
Pseudophorus minutus
Pseudozygopleura sp.
Stegocoelia abrupta
Stegocoelia compactoidea
Straparollus sp.

CEPHALOPODS

Woody Cove

Michelinoceras sp. indet.
Poterioceras sp. Bell

TRILOBITA

Capelin Cove

Paladin eichwaldi

Woody Cove

Paladin eichwaldi

Plus unidentified ostracods.

Fauna listed from three fossil bearing horizons in Woody Cove and two in Capelin Cove collected and identified by G. McGlynn (personal communication, 1979), with additional forms (italics) added from Hayes and Johnson (1938) and Utting (1966).

MIOSPORES

Apiculatisporis sp.,
Auroraspora macra,
Calamospora sp.,
Crassispora trychera,
Cyclogranisporites palaeophytus,
Dictyotriletes sp.,
Endosporites micromanifestus,
Granulatisporites tuberculatus,
Knoxisporites stephanephorus,
Lycospora noctuina var noctuina,
Punctatisporites planus,
Retusotriletes incohatus,
Rugospora minuta,
Schopfites claviger,
Spelaeotriletes sp.,
Verrucosisporites morulatus

Assemblage collected from four samples in Capelin Cove, identified by J. Utting (personal communication, 1978); spore preservation generally poor.

CONODONTS

Apatnognathus spp.
Cavusgnathus windsorensis
Cavusgnathus regularis
Gnathodus sp.
Gnathodus bilineatus
Gnathodus girtyi
Mestognathus spp.
Ozarkodina laevipostica
Spathognathus n.sp. A.
Spathognathus campbelli
Spathognathodus scituleis

Plus several unidentified elements, genus and species.

Assembled from several stations in section in Capelin Cove collected and identified by von Bitter and Plint-Geberl (1982)

Table 9: Fauna and microflora compiled for the Mollichignick Member (Robinsons River Formation) and the Woody Cape Formation.

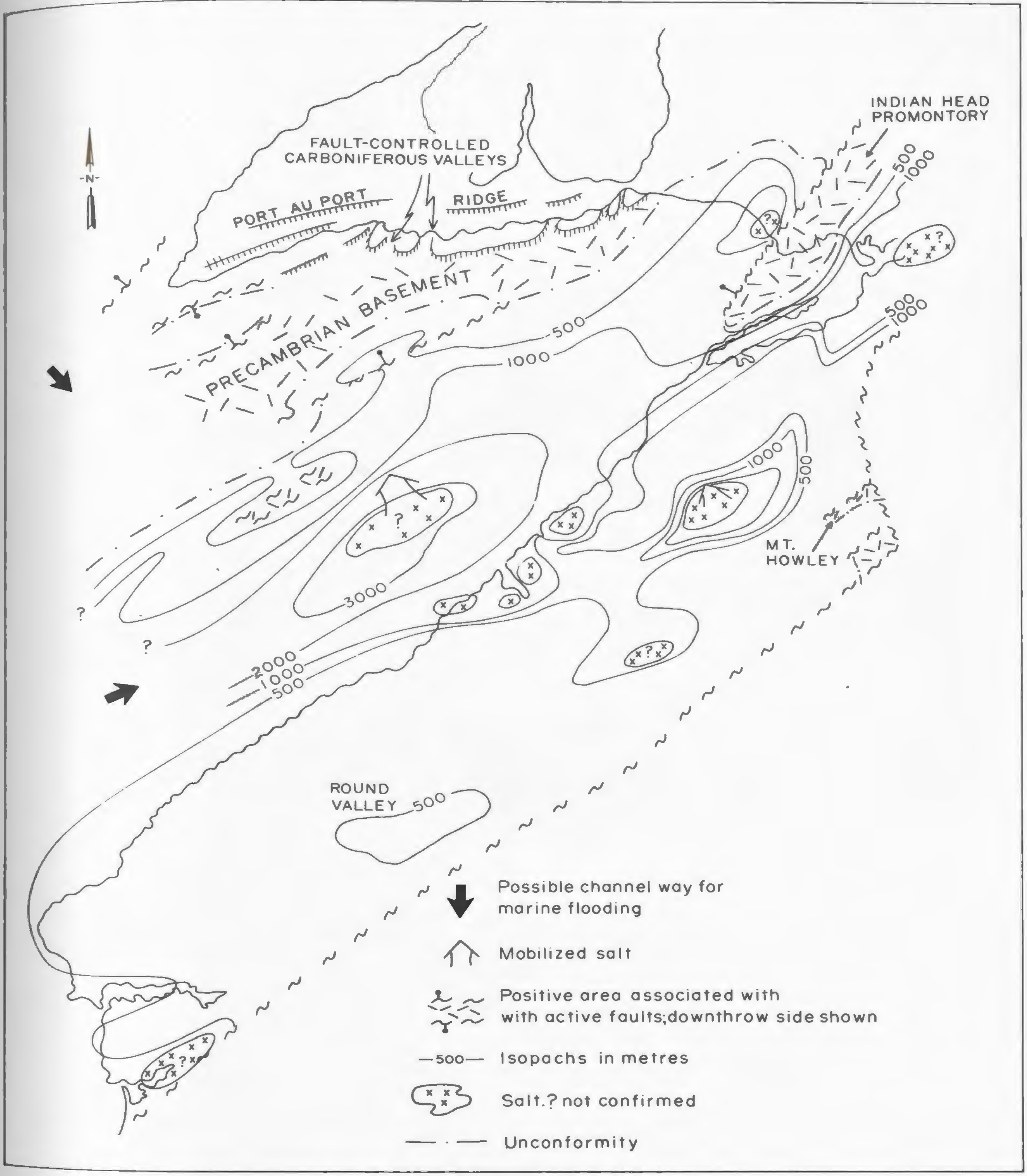


Figure 33: Partly speculative isopach map of the Bay St. George subbasin during deposition of the lower part of the Robinsons River Formation. Data compiled from drill holes, gravity and aeromagnetic maps, structural cross sections, logged sections and offshore seismic surveys. Structural highs, probable active faults and location of possible salt-filled depressions shown.

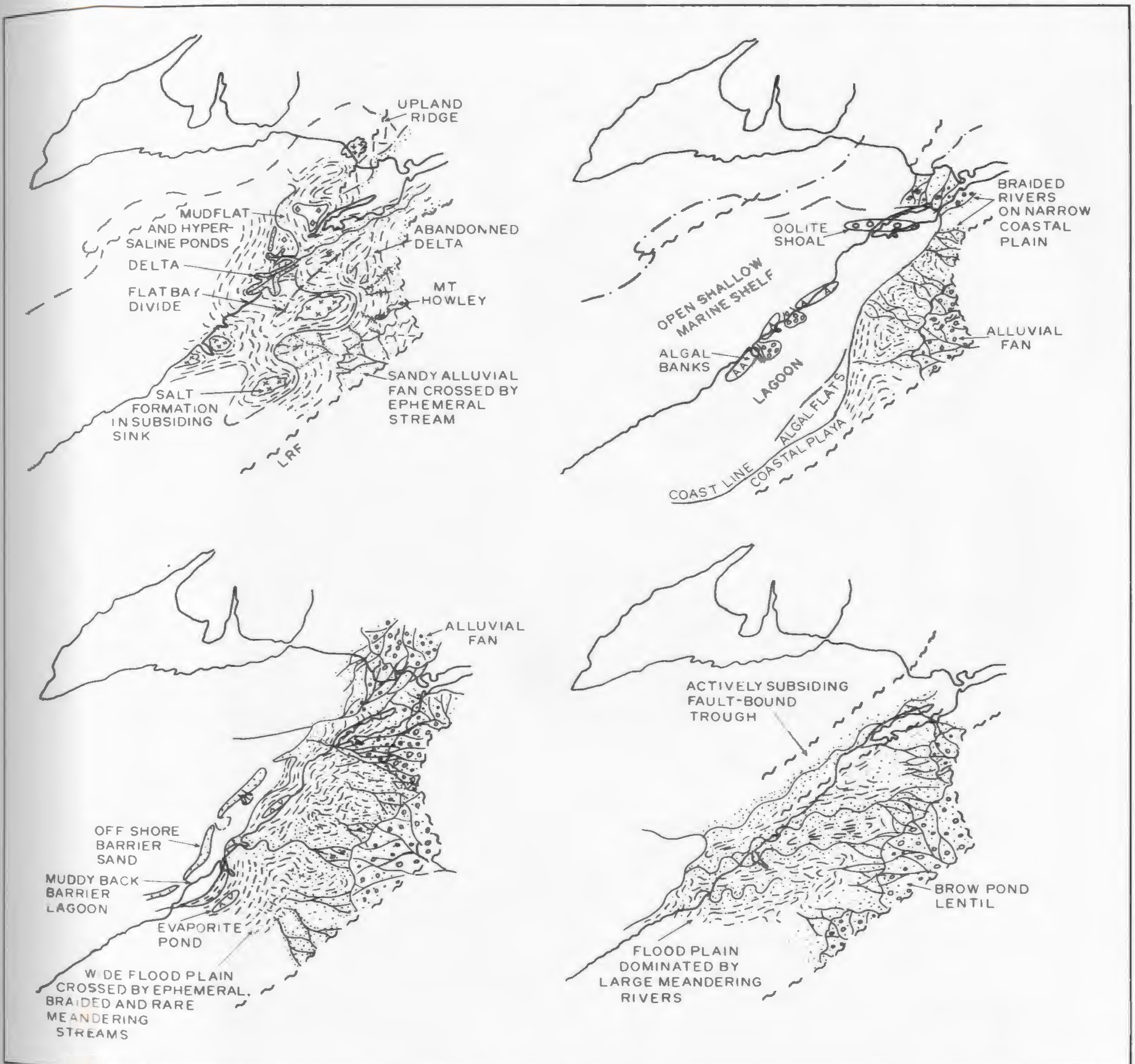


Figure 34: Possible reconstruction of the paleogeography of the northern part of the Bay St. George subbasin during the deposition of the Jeffrey's Village and Highlands Members of the Robinsons River Formation. (A) lower Jeffrey's Village Member; (B) lower part of upper Jeffrey's Village Member during widespread marine flooding; (C) dominantly nonmarine sedimentation in upper part of the Jeffrey's Village Member; (D) Highlands Member.

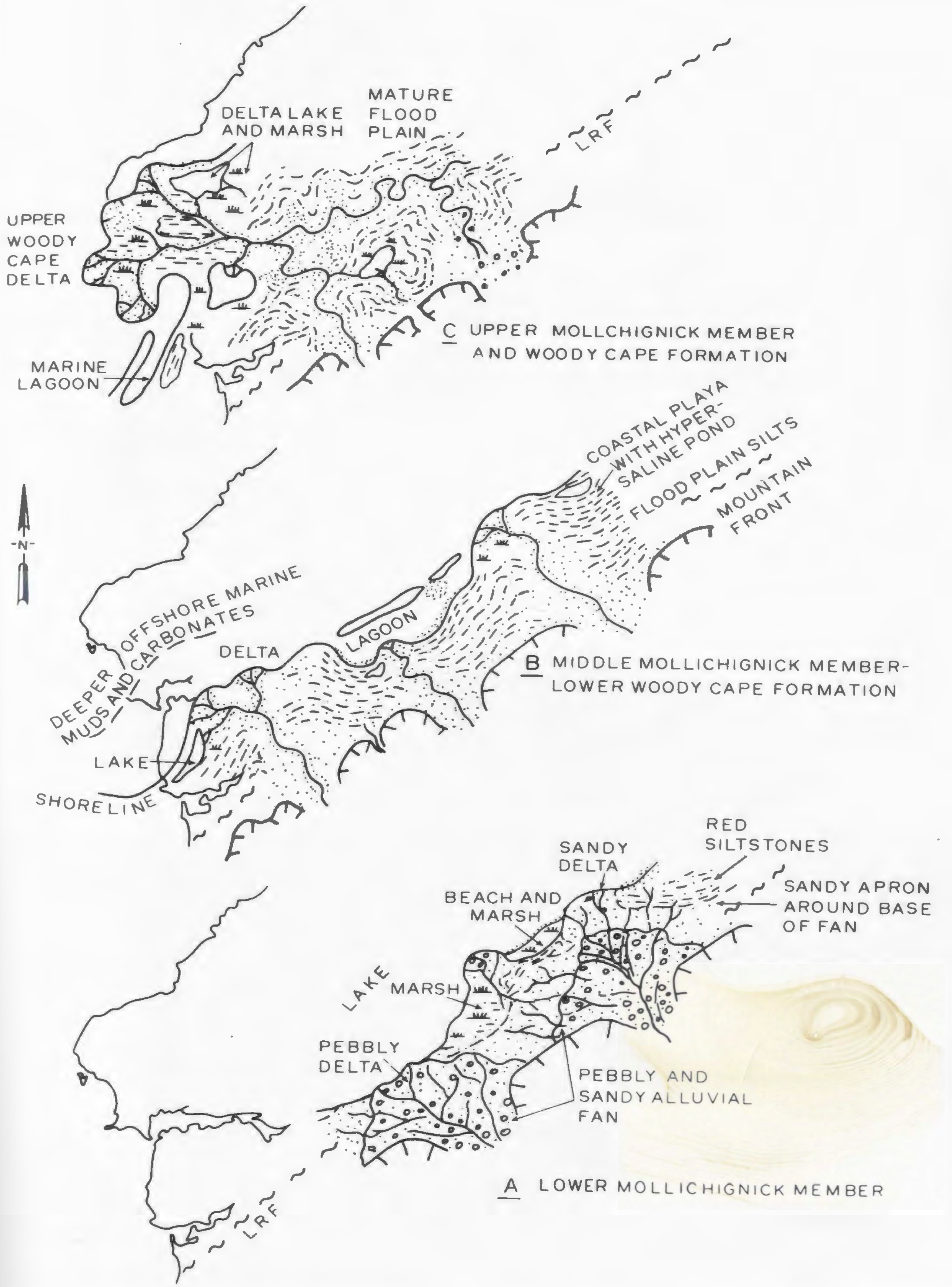


Figure 35: Probable paleogeography of Mollichignick Member, Robinsons River Formation and the Woody Cape Formation in the last stages of deposition of the Codroy Group. Overfall Brook Member is not illustrated.

Plate 125: Black shale with limestone laminae, beds and concretions (lithofacies A), base of type section of Woody Cape Formation. Measuring stick 1 m long.

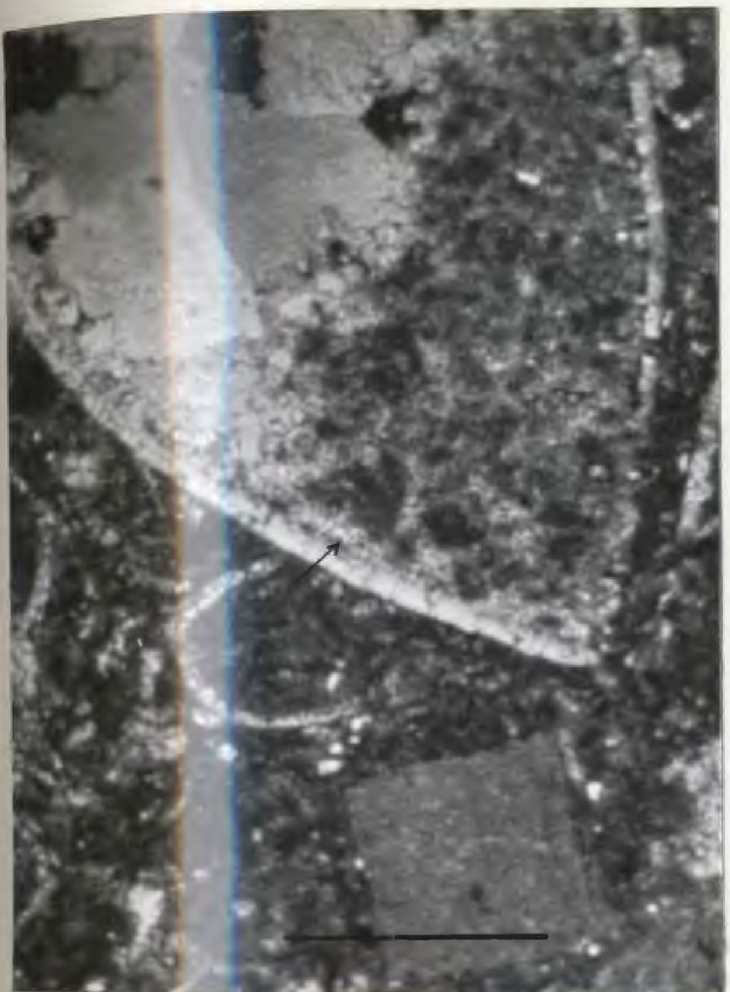
Plate 126: Shale and shaly mudstone intercalated with black lumpy dolomite and limy dolomites, lithofacies A, Woody Cape Formation, Capelin Cove; sequence inverted.

Plate 127: Coarsening-upward sequence of sheet-like deposits of mudstone, siltstone and silty sandstone, lithofacies D and E, Woody Cape Formation. These deposits are cut into by a channel that is filled by crossbedded and planar laminated sandstone (lithofacies F). The channelled sandstone is in turn overlain by interbedded mudstones and siltstones (lithofacies D) capped by a thick sheet of sandstone composed entirely of climbing ripple-drift with current direction downdip, i.e. southwards. Type section, north of Woody Cape.

Plate 128: Interbedded siltstones and mudstones of lithofacies D, Woody Cape Formation, Capelin Cove. Middle siltstone bed lies gradationally above mudstones in coarsening upward unit. Beds inverted. Ruler is 1 m long.

Plate 129: Ripple cross-laminated, sandy siltstone gradationally overlying cross-laminated silty mudstone of lithofacies D, Woody Cape Formation. The silty mudstones overlie a massive blue-gray mudstone such as that above the sandy siltstone. Type section, just north of Woody Cape. Pen for scale.

Plate 130: Composite unit of sandstone with sheeted geometry, lithofacies E, Woody Cape Formation. Type section, north of Woody Cape. Hammer for scale.



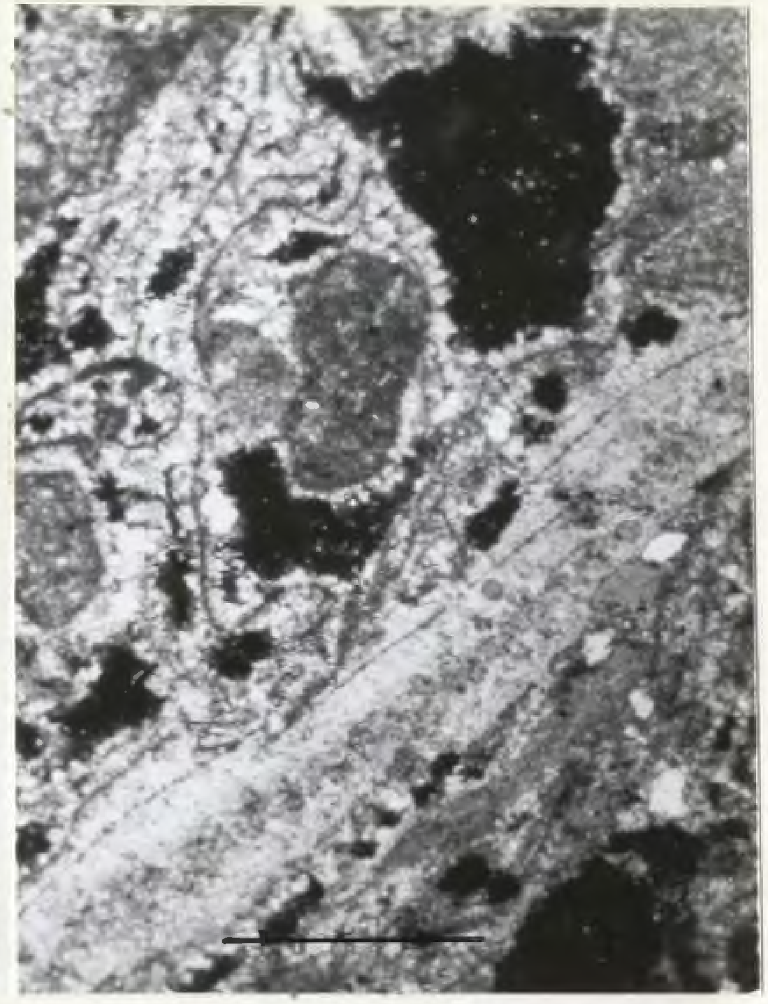


Plate 131: Crinoid and ostracod fragments and a whole brachiopod in skeletal wackestone, lithofacies H, Woody Cape Formation, Capelin Cove. Brachiopod was filled by geopetal mud, pendant cement and blocky spar. Local development of early acicular cement (arrow) was curtailed by accumulation of geopetal mud.

Plate 132: Photomicrograph of calcarenite of lithofacies H, Woody Cape Formation, composed of elongate phylloid algal fragments outlined by micrite envelopes, isopachous cement and mosaic spar. The phylloid thalli are mixed elsewhere in the slide with crinoidal fragments and other skeletal and non-skeletal grains. Top of Capelin Cove section, associated with wackestones of Plate 131. Bar-1mm.

TABLE 10: Correlation of rock units in the Codroy Group of the Bay St. George Subbasin, western Newfoundland and the Windsor Group, Nova Scotia (based on Boyle, 1963; Shea, 1966; Moore and Ryan, 1976, Giles, 1977; Utting, 1980; Boehner, 1981a)

NOVA SCOTIA		SUBZONE	BAY ST. GEORGE SUBBASIN	
LITHOLOGY	FORMATION		FORMATION	LITHOLOGY
Red siltstones, sandstones, limestones, minor gypsum-anhydrite	GREEN OAKS FORMATION: *Includes KENNETCOOK, MUSQUEDOIT & WALLACE POINT LIMESTONES*	*E*	*ROBINSONS RIVER FORMATION*: *OVERFALL BROOK MEMBER*; *WOODY CAPE FORMATION*	*Red pebbly arkosic sandstones (345 m)*; *Gray-green mudstones, siltstones, sandstones, black carbonates, black shales (690 m)*
	GREEN OAKS FORMATION: *Includes MEANDER RIVER and AVON LIMESTONES*	*D*	*MOLLICHIGNICK MEMBER*; *~~~ ? ~~~*	*Red siltstones, sandstones, conglomerates, minor limestones, some gray beds (2275 m)*
	GREEN OAKS FORMATION: *Includes HERBERT RIVER and BROOKLYNN STATION LIMESTONES*	*C*	*? HIGHLANDS MEMBER*; *~~~ ? ~~~*	*Red sandstones siltstones, minor limestone (1200 m +)*
Limestones, gypsum-anhydrite, minor salt, siltstones, sandstones	*WENTWORTH FORMATION and MILLER CREEK FORMATION inc. MILLER CREEK & MAXNER LIMESTONES*; *MacDONALD ROAD FORMATION*	*B*	*JEFFREY'S VILLAGE MEMBER*	*Fine redbeds, limestones, gypsum, fine drab beds, sandstones, salt (1400 - 2000 m)*
Red siltstone ± minor gypsum-anhydrite	*TENNYCAPE FORMATION*; *CARROL'S CORNER FORMATION*	*A*	*CODROY ROAD FORMATION*	*Black limestones, gypsum or anhydrite*
Salt, anhydrite gypsum, limestone dolomite	*VINLAND FORMATION*; *STEWIACKE FORMATION*			*Gray shales, evaporitic gray shales, gypsum, anhydrite, red siltstones and mudstones; some black limestone, possible salt (120 - 245 m)*
Laminated argillaceous limestone, algal mounds and shelly bioherms	*MACUMBER FORMATION*		*SHIP COVE FORMATION*	*Laminated argillaceous limestones (13 - 25 m)*

Appendix A - Summary of Stratigraphic Units

NAME:	*ANGUILLE GROUP*
AGE:	Late Devonian?-Early Carboniferous
AUTHOR:	Baird and Cote, 1964; Cote, 1964
TYPE LOCALITY:	Anguille Mountains, southwestern Newfoundland (1:50,000 maps, 110/14, 12B/2, 12B/3, 110/14.
LITHOLOGY:	Gray and red sandstones, conglomerates, black and grey shales, minor dolostones and limestones, deposited in lacustrine and fluviatile environments.
THICKNESS AND DISTRIBUTION:	6000 m+ in the Anguille Mountains and Bald Mountain. (110/14, 12B/3, 12B/2). Only 150-200 m of strata belonging to the group occur in the Flat Bay area (12B/2 and 12B/7).
RELATIONS TO OTHER UNITS:	Basal Contact: Base is not exposed in the Anguille Mountain; Strata belonging to the Anguille Group unconformably overlie Grenvillian basement at Flat Bay; Upper contact: The Anguille Group is conformably overlain by Codroy Group in both areas and is defined to include all strata below the Ship Cove Formation.
AGE JUSTIFICATION:	Plant fossils, (Bell, 1948), Microspores (Cote, 1964).
HISTORY:	First named Anguille Series by Hayes and Johnson (1938) and later Bell (1948) for strata of Anguille Mountains. Later called Anguille Group by Baird and Cote, 1964, Belt, (1969), Knight (1983).
REFERENCES:	Hayes and Johnson, (1938); Bell (1948); Baird (1960);Baird and Cote (1964); Cote (1964); Belt (1969), Knight (1983).

NAME:	*KENNELS BROOK FORMATION*
AGE:	Late Devonian? - Early Carboniferous
AUTHOR:	Knight, I. (1983)
TYPE LOCALITY:	Northwest limb of the Anguille anticline, Anguille Mountains (map sheets, 110/3 and 110/14).

LITHOLOGY: Red and green-gray sandstones, pebbly sandstones, conglomerates and red cleaved siltstones in lower part of the formation; some fining upward sequences. Upper sequence of green-gray and brown interbedded mudstones and very fine sandstones, minor caliche limestones; fluviatile and shallow lacustrine? sediments.

THICKNESS AND DISTRIBUTION: 3200+m in centre of Anguille Anticline including 2200m in a drill hole (Union-Brinex, 1973; Knight, 1983b). Found only in centre of Anguille Anticline and along the faulted northwest limb of this anticline.

RELATIONS TO OTHER UNITS: Basal Contact: no base known in drill hole (Union Brinex, 1973); metamorphism increases downward; Upper Contact: upper boundary is sharp and conformable (although locally thrusted) and is placed where interbedded gray sandstones and mudstones or red beds of the formation are overlain by black shales of overlying Snakes Bight Formation.

AGE JUSTIFICATION: Age uncertain, microspore data (Cote, 1964) suggests early Tournaisian; Belt (1969) first suggested the unit was probably Devonian in part.

HISTORY: The Kennels Brook Formation is named for the basal formation of the Anguille Group. It is a new name proposed to replace Baird and Cote's (1964) Cape John Formation which was wrongly defined using inverted strata of the younger Spout Falls Formation (their Seacliffs Formation).

REFERENCES: Union-Brinex (1973); Baird and Cote (1964); Belt (1969); Knight (1983).

NAME: *SNAKES BIGHT FORMATION*

AGE: Tournaisian

AUTHOR: Baird and Cote, (1964)

TYPE LOCALITY: Hynes Gulch, (12B/3), Snakes Bight (110/14)

LITHOLOGY: Intercalated beds and sequences of black shales/ mudstones and gray, lithic and subarkosic sandstones; minor quartz and dolostone intraclastic conglomerates, intraformational slump breccias and some dolostones also occur. Sequence interpreted to have been laid down as deepwater lacustrine sequence of basin floor muds, turbidite sandstones and thick, sublacustrine and deltaic sands.

THICKNESS AND DISTRIBUTION: Widely distributed in the Anguille Mountains in Codroy (11 O/14) Friars Cove (12B/3) and St. Fintans (12B/2) map sheets. 785 m in type section; approximately 1000 m in centre of mountains.

RELATIONS TO OTHER UNITS: Basal Contact: The base of the formation is sharp and conformable upon Kennels Brook Formation although contact is locally affected by thrust faults. It is placed at base of first bed of black shale or mudstone. Upper Contact: The formation is conformably overlain by Friars Cove Formation which is distinguished by the dominance of gray sandstones and absence of black lutites in preference to gray. The upper contact is placed at the base of a conglomeratic sandstone sequence belonging to the Friars Cove formation.

AGE JUSTIFICATION: No good data available; plant fragments (Bell, 1948) suggest it is Tournaisian in age.

HISTORY: First called the Snakes Bight shale by Hayes and Johnson (1938) and formally defined as the Snakes Bight Formation by Cote (1964); Baird and Cote (1964).

REFERENCES: Hayes and Johnson (1938); Baird and Cote (1964); Cote, (1964); Knight (1983).

NAME: *FRIARS COVE FORMATION*

AGE: Tournaisian

AUTHOR: Knight (1983)

TYPE LOCALITY: Friars Gulch

LITHOLOGY: Gray, thick-bedded sandstones with subordinate gray shales, conglomeratic sandstones, some red sandstones, minor limestones and carbonate; The formation is interpreted to have been laid down in fluvial-deltaic and shallow lacustrine settings.

THICKNESS AND DISTRIBUTION: 500 m in type section; 1300 m in central part of Anguille Mountains. The formation is confined to the Anguille Mountains (12B/2, 12B/3, 11 O/14).

RELATIONS TO OTHER UNITS: Basal Contact: Conformably to locally disconformable overlying the Snakes Bight Formation. The basal contact of the formation is placed at the base of a gray, conglomeratic sandstone sequence mapped throughout the Anguille Mountains. The contact occurs above the last black lutite unit belonging to

Snakes Bight Formation. In the south of the Anguille Mountains, the Friars Cove Formation lies conformably and sharply beneath the Ship Cove Formation of the Codroy Group; in the north of Anguille Mountains they lie gradationally beneath red beds of the Spout Falls Formation of the Anguille Group.

AGE JUSTIFICATION: No information

HISTORY: The formation was the lower part of the Seacliffs sandstones and Seacliffs Formation of the Baird (1951) and Baird and Cote (1964).

REFERENCES: Knight (1983); Baird, (1951); Baird and Cote (1964).

NAME: *SPOUT FALLS FORMATION*

AGE: Tournaisian

AUTHOR: Knight, (1983)

TYPE LOCALITY: The Spout Gulch, Anguille Mountains (12B/2, St. Fintans map sheet); also includes Fischells conglomerate member.

LITHOLOGY: Red and some gray-green, sheeted sandstones, minor red siltstones and conglomerates in Anguille Mountains; in Falt Bay anticline the formation is represented by the Fischells conglomerate member composed of gray conglomerates and flaggy sandstones. Arkosic sandstones and conglomerates of the basal half of the Brow Pond lentil may also be part of the formation. Distinct from the underlying Friars Cove Formation by the absence of gray shales, presence of red lutites, predominance of red sandstones over gray, and the characteristic sheeted nature of beds. Sedimentary rocks of the formation are interpreted as the deposits of shallow ephemeral and perennial braided streams.

THICKNESS AND DISTRIBUTION: 780 m in type section, thickens to 2250 m in northeast of Anguille Mountains. Distributed around the northeast part of the Anguille Mountains and beneath Bald Mountain.

RELATIONS TO OTHER UNITS: Basal Contact: The Spout Falls Formation lies gradationally above the Friars Cove Formation. The base is placed at the base of the first thick (1 m) bed of red sandstone and above the last thick unit of interbedded gray sandstone and shale typical of the Friars Cove Formation. Upper Contact: The Formation is sharply and conformably overlain by Ship Cove Formation of the Codroy Group (see also Fischells Conglomerate Member). Thins southward where it passes into gray sandstones mapped as the Friars Cove Formation.

AGE JUSTIFICATION: None

HISTORY: Originally the upper red part of the Seacliffs Formation of Baird and Cote (1964) and the Seacliffs sandstone (Baird, 1949, 1951).

REFERENCE: Knight (1983); Baird and Cote (1964); Baird (1949, 1951).

NAME: *FISCHELLS CONGLOMERATE MEMBER, SPOUT FALLS FORMATION, ANGUILLE GROUP.*

AGE: Tournaisian?; possibly early Visean

AUTHOR: Baird, 1951, Knight (1983)

TYPE LOCALITY: Fischells Brook, west and east limb of the Flat Bay anticline, (12B/7).

LITHOLOGY: Gray pebble and cobble conglomerates, and flaggy sandstones, believed to be alluvial fan deposits derived from erosion of Cambro-Ordovician platformal rocks now found north of the subbasin.

THICKNESS AND DISTRIBUTION: 100-150 m thick on Fischells Brook, 200 m on Coal Brook, 2 m on Romaines Brook. Around Flat Bay anticline, St. Georges Bay lowlands (12B/7), from Flat Bay Brook to north of Robinsons River; near Steel Mountain on Coal and Sheep Brooks; Romaines Brook.

RELATIONS TO OTHER UNITS: Basal Contact: Unconformably upon Grenvillian rocks on the Flat Bay anticline and faulted against crystalline basement near Steel Mountain. Conformably overlain by Ship Cove Formation of the Codroy Group.

AGE JUSTIFICATION: No information; possibly early Visean or late Tournaisian.

HISTORY: Although Baird (1951) first referred to the unit as the Fischells conglomerate, it was later called the Fischells Brook Formation by Belt (1969) who appears to also include shales and carbonates from the overlying Ship Cove Formation.

REFERENCES: Knight (1983); Baird, (1951); Belt (1969).

NAME: *CODROY GROUP*

AGE: Middle to late Visean and perhaps early Namurian

AUTHOR: Riley, 1962, Baird and Cote, 1964, Knight (1983).

TYPE LOCALITY: Codroy (11 O/14).

LITHOLOGY: Intercalated coarse to fine grained red beds, evaporites including sulphate and chloride salts, limestones and dolostones, some gray lacustrine and marine siliciclastics. Comprises Ship Cove, Codroy Road, Robinsons River and Woody Cape Formations.

THICKNESS AND DISTRIBUTION: 6000+m; Distributed in the Codroy lowlands (11 O/14), and St. Georges Bay lowlands from Ship Cove north to Stephenville, and east to the foot of the Long Range Mountains (12B/2, 12B/7 and 12B/8).

RELATIONS TO OTHER UNITS: Basal Contact: The Codroy Group conformably overlies the Anguille Group in Bay St. George subbasin; although it lies unconformably upon Grenvillian and Lower Paleozoic basement on Port au Port Peninsula and Indian Head. Upper Contact: No stratigraphic upper contact is known as the group is in faulted contact with the younger Barachois Group. Codroy Group is equivalent of the Windsor Group of Nova Scotia.

AGE JUSTIFICATION: By comparison to studies on the Windsor Group of Nova Scotia, macrofossils (brachiopods, bivalves gastropods; Bell, 1948, 1929, Moore & Ryan, 1976) suggest a middle to late Visean age; foraminifera (Mamet, 1968, 1970) conodonts (von Bitter and Plint Geberly, 1982, Baxter and von Bitter, 1979), spores (Utting, 1978, 1980, Knight, 1983) support middle to late Visean age. Conodonts (Globensky, 1967) and foraminifera (Mamet, 1970) suggest the Windsor Group may be late Visean and Early Namurian in age.

HISTORY: Murray (1873, in Murray and Howley, 1881) called these rocks the Windsor marine series as did Schuchert and Dunbar (1934). Hayes and Johnson (1938) and Bell (1948) first called it the Codroy Series. Riley (1962) Baird (1951 & 1959), Baird and Cote (1964) later called it the Codroy Group. The definition of the group is the same in each case.

REFERENCES: Murray and Howley (1881); Schuchert and Dunbar, (1934); Bell (1929, 1948); Baird (1951, 1959); Baird and Cote, (1964); Riley, (1962); Hayes and Johnson (1938); Moore and Ryan (1976); Utting (1978, 1980); Knight (1983b) Mamet (1968, 1970); von Bitter and Plint-Geberl, (1982); Baxter and von Bitter, (1979).

NAME: *SHIP COVE FORMATION*

AGE: Visean

AUTHOR: Bell (1948), Knight (1983)

TYPE LOCALITY: Ship Cove, St. Georges lowlands, (12B/2).

LITHOLOGY: Gray, ribbon-laminated, crypt-algal limestone and shales. It also includes minor sandstones, intraformational breccias, red and green shales and some fossils; gypsum molds are common in upper part of formation.

THICKNESS AND DISTRIBUTION: 13-20m; locally 5-8 m where top of the formation is replaced by displacive gypsum; 25m on Fischells Brook. Exposed around Flat Bay anticline and peripheral to Anguille and Bald Mountains; also outcrops at Romaines Brook, Boswarlos, and on Codroy Island.

RELATIONS TO OTHER UNITS: Basal Contact: The Ship Cove formation sits sharply and conformably upon the Friars Cove Formation in the southwest of the Anguille Mountains and upon the Spout Falls Formation of the Anguille Group in the northeast of the Anguille Mountains and on Bald Mountain. It is also conformable upon Fischells conglomerate member on Fischells Brook and Romaines Brook. Upper Contact: The Ship Cove Formation is conformably overlain by gypsum (in north of subbasin), gray shales (at Ship Cove) and fine red and gray beds (in Codroy lowlands) of the Codroy Road Formation.

AGE JUSTIFICATION: Conodonts, Cavusgnathus windsorensis and Diplognathus, suggest middle Visean age (von Bitter and Plint-Geberl, 1982). The Formation is equivalent of the Macumber Formation of the Windsor Group, Nova Scotia.

HISTORY: Bell (1948) first described and named the limestone. The name was retained by later workers including Baird (1949, 1951) and Knight (1983).

REFERENCES: Knight (1983); Brown and Knight (1976), Bell (1948), von Bitter and Plint-Geberl (1982). Baird (1949, 1951).

NAME: *CODROY ROAD FORMATION*

AGE: Visean

AUTHOR: Knight (1983)

TYPE LOCALITY: Cliff section from mouth of Ship Cove Brook northward to Cormorant Rock (12B/2). Codroy to Black Point, Codroy coastal section (11 0/14).

LITHOLOGY: Gypsum, anhydrite, gray shales and silty mudstones, black dolostones and skeletal limestones, red siltstones and very fine sandstones, possible salt. Interpreted to be deposited in shallow, hypersaline seas flanked by evaporitic sabhkas in the north and a prograding floodplain that was periodically inundated by marine flooding.

THICKNESS AND DISTRIBUTION: 145 m on Fischells Brook, 120 m at Ship Cove, possibly 300 m at type section. Formation is mapped in low country skirting the Anguille Mountains and Bald Mountain. Folded around Flat Bay anticline, Flat Bay. Romaines Brook, west of Stephenville.

RELATIONS TO OTHER UNITS: Basal Contact; The Codroy Road Formation conformably overlies the limestones of the Ship Cove Formation. Upper Contact: The formation is overlain conformably and diachronously by Jeffreys Village Member of the Robinsons River Formation. Upper contact placed above Black Point limestone, Codroy (11 0/14), Cormorant limestone and gypsum, near Ship Cove (12B/2) and top of gypsum bed on Fischells Brook (12B/7).

AGE JUSTIFICATION: Conodonts and Shelly fauna suggest middle Visean age. Straddles subzones A and lower B of Windsor Group.

HISTORY: The Codroy Road Formation seems to take in the Black Point limestone and Codroy shales and gypsum of Hayes and Johnson, (1938) the Black Point limestone and gypsiferous zone of Bell (1948) and Lower Codroy of Baird and Cote (1964). It has also been called informally the Woodville formation by Knight (in Brown and Knight, 1976).

REFERENCES: Knight (1983); Brown and Knight, (1976); Hayes and Johnson, (1938); Bell (1948); Baird and Cote (1964).

NAME:	*ROBINSONS RIVER FORMATION(CODROY GROUP)*
AGE:	Visean
AUTHOR:	Knight, 1983
TYPE LOCALITY:	Bay St. George subbasin.
LITHOLOGY:	Composed of Jeffreys Village, Highlands, Mollichignick and Overfall Brook Members. A mixed assemblage of coarse to fine red beds, gray lutites and sandstones deposited in lacustrine and marine settings, marine dolomitic and lime carbonates and evaporites.
THICKNESS AND DISTRIBUTION:	5000+m; St. Georges Bay and Codroy lowlands, southwest Newfoundland; (Stephenville map area 12B, Port aux Basques map area, 11 O).
RELATIONS TO OTHER UNITS:	Conformably overlies Codroy Road Formation. In part equivalent to the Woody Cape Formation.
AGE JUSTIFICATION:	Shelly fauna, microfauna, and microspores suggest it spans Windsor subzones upper B to at least D. (Knight, 1983, Bell, 1948, von Bitter and Plint-Geberl, 1982).
HISTORY:	Rocks previously described by Bell (1948) but not assigned to any formation. In general, they were placed previously in the upper Codroy Group (Baird and Cote, 1964). In the Codroy lowlands, rocks belonging to parts of the formation were mapped and defined informally by Knight (in Brown and Knight, 1976) as the North Branch Formation.
REFERENCES:	Knight (1983); Bell (1948); Baird and Cote (1964); Brown and Knight (1976); von Bitter and Plint-Geberl (1982).

NAME:	*JEFFREYS VILLAGE MEMBER (ROBINSONS RIVER FORMATION, CODROY GROUP)*
AGE:	Visean
AUTHOR:	Knight, I. (1983)
TYPE LOCALITY:	Fischell's Brook and coast of St. Georges Bay from Fischells Brook, south to Crabbes River, St. Georges Bay lowlands (12B/7, 12B/2).
LITHOLOGY:	Dominantly non-marine and some marine siliciclastic rocks including red and gray shales, mudstones, siltstones, sandstones and conglomerates, interbedded with carbonates and evaporites. Evaporites include anhydrite, gypsum, halite and potassic salts; carbonates include caliche limestones, and a variety of dolomitic,

argillaceous and fossiliferous limestones and dolostones. Succession consists of a lower sequence of gray, fine siliciclastics and evaporites, above this beds of marine carbonates are interspersed with fine to coarse red beds.

THICKNESS AND DISTRIBUTION: 1400-2100m in type section and adjacent areas of St. Georges Bay lowlands. Underlies much of the St. Georges Bay lowlands (12B/2, 12B/7) and also areas of the Codroy lowlands locally known as the "round valley" (Knight, 1983).

RELATIONS TO OTHER UNITS: Basal contact: The Jeffreys Village Member in the Fischells Brook section lies conformably upon gypsum of the Cordoy Road Formation. Upper Contact: It is overlain conformably by Highlands Member, the upper boundary being placed at the top of the Crabbes Limestone.

AGE JUSTIFICATION: Shelly fauna (Bell, 1948, Knight, 1983) conodonts (von Bitter and Plint-Geberl, 1982) the foraminifera (Mamet, 1968) suggest it is Visean in age, conforming to Windsor subzones upper B to lowest C of the Windsor Group of Nova Scotia.

HISTORY: These strata were described but not placed in any rock unit by Hayes and Johnson (1934) or Bell (1948). Bell (1948) suggested they may be in part equivalent to basal beds of the Woody Cape Formation (his Woody Cove Beds).

REFERENCES: Knight, I (1983); Hayes and Johnson, 1938); Bell, 1948; von Bitter and Plint-Geberl, 1982.

NAME: *HIGHLANDS MEMBER*

AGE: Visean

AUTHOR: Knight, I. (1983)

TYPE LOCALITY: Coastal section south of the mouth of Crabbes River southwards to Highlands River. Section measured on north limb of St. Davids syncline.

LITHOLOGY: Red, with rare green and yellow, calcareous sandstones intercalated with red siltstones in repetitive fining upward sequences; some intraformational conglomerates, composed of caliche and mudclasts pebbles, caliche limestones, two beds of fossiliferous and cryptalgal limestone and ripple bedded, white sandstones. These beds are interpreted to be floodplain and channel deposits of meandering rivers.

THICKNESS AND DISTRIBUTION:	Thickness of the member is more than 880m but at least 200 to 500 m may occur in offshore beds concealed beneath waters of St. Georges Bay. The member outcrops in the cove of the St. Davids Syncline.
RELATIONS TO OTHER UNITS:	Basal Contact: Red sandstones of the Highlands Member sit sharply and conformably upon limestone of the Crabbes Limestone of the Jeffreys Village Member. Upper Contact: not known.
AGE JUSTIFICATION:	None but overlies the Crabbes Limestone known to carry a shelly and microfossil fauna of Visean age and similar to that of subzone C of the Windsor (Knight, 1983; Bell, 1948; Mamet, 1968; von Bitter and Plint-Geberl, 1982).
HISTORY:	The member was first called the Highlands sandstone by Baird, (1959). The unit was placed in the upper Codroy by Bell (1948) and Baird and Cote (1964).
REFERENCES:	Knight, I., 1983; Bell, 1948; Baird (1959), Baird and Cote, (1964); Mamet, 1968; von Bitter and Plint-Geberl, 1982.

NAME:	*MOLLICHIGNICK MEMBER (ROBINSONS RIVER FORMATION, CODROY GROUP)*
AGE:	Visean
AUTHOR:	Knight, I., 1983.
TYPE LOCALITY:	Commences 3.2 km upstream of the junction of the North Branch River and the Grand Codroy River and continues along the Grand Codroy River to 750 m from mouth of the tributary stream, Overfall Brook (11 O/14).
LITHOLOGY:	Red siltstones, red and gray, micaceous sandstones, argillaceous and pebbly arkosic sandstones, caliche limestones, gray lacustrine mudstones, siltstones, sandstones and carbonates; gray, fossiliferous marine shales, sandstones and dolostones. Many fining upward fluvial sequences; megasequences and basin-fill sequences of sandstones and conglomerates along margin of Bay St. George subbasin. The sedimentary rocks are interpreted to be deposited dominantly in floodplain and alluvial fan settings close to the Long Range fault. Lacustrine and shallow marine conditions also occurred at different intervals.

THICKNESS AND DISTRIBUTION: 2275+m known only from the inner area of the Codroy lowlands. (11 0/14 Codroy; 11 0/15, Grandys Lake.)

RELATIONS TO OTHER UNITS: Basal Contact: The base of the member is everywhere faulted. Upper Contact: The member is conformably overlain by the Overfall Brook Member. The boundary is placed at base of the continuous succession of pink arkosic sandstones of the Overfall Broook Member where they overlie gray and red muddy sandstones and siltstones of the Mollichignick Member.

AGE JUSTIFICATION: Shelly fauna and microspores(Knight, 1983) suggest the member belongs at least to Windsor subzones D.

HISTORY: Generally this rock sequence was overlooked by previous workers except Utting (1966) who assigned some of the unit to Windsor subzone B and other parts to the Barachois Group. Baird and Cote (1964) included it in the Upper Codroy Group.

REFERENCES: Knight (1983), Utting, J., (1966); Baird and Cote, (1964).

NAME: *OVERFALL BROOK MEMBER (ROBINSONS RIVER FORMATION, CODROY GROUP)*

AGE: Visean-Namurian?

AUTHOR: Knight, I (1983)

TYPE LOCALITY: Overfall Brook and Grand Codroy River from 750 m north of the mouth of Overfall Brook (11 0/14, Codroy).

LITHOLOGY: Red, pink and white, pebbly and gritty, arkosic sandstones, with some red siltstones and gray carbonaceous mudstones, siltstones and sandstones. Sedimentary rocks interpreted to be deposited in sandy and gravelly braided streams on a alluvial fan.

THICKNESS AND DISTRIBUTION: 345+m; found in the Codroy lowlands only near edge of Bay St. George subbasin (Codroy sheet, 11 0/14).

RELATIONS TO OTHER UNITS: Basal Contact: The formation is conformable,though locally erosive,upon beds of the Mollichignick Member. The boundary is placed at the base of the first thick, continuous sequence of arkosic sandstones overlying fine red and gray muddy siltstones and fine sandstone of the Mollichignick Member. No top is known.

AGE JUSTIFICATION:	None. Youngest rocks of the Codroy Group but may be in part Namurian in age.
HISTORY:	Previously assigned to the Barachois Group by Utting (1966), Baird and Cote (1964), and Belt (1969) but not formally defined.
REFERENCES:	Knight (1983); Baird and Cote, (1964); Belt, (1969); Belt, (1969).

NAME:	*WOODY CAPE FORMATION*
AGE:	Visean
AUTHOR:	Knight (1983)
TYPE LOCALITY:	Coastal cliffs from Woody Cove to Woody Cape and Capelin Cove, Codroy lowlands (Codroy map sheet 11 O/14).
LITHOLOGY:	Green-gray, green and minor red mudstones, siltstones, micaceous and subarkosic sandstones, black to gray fossiliferous shales, fossiliferous and unfossiliferous, limestones and dolostones. Shallow marine and fluvial deltaic depositional environment.
THICKNESS AND DISTRIBUTION:	690+m; found only in the immediate area of Woody Cape and Capelin Cove (Codroy map area 11 O/14) Hayes and Johnson (1938) suggest some outcrops occur in the bed of the Little Codroy River.
RELATIONS TO OTHER UNITS:	Faulted boundaries with older (Codroy Road Formation) and younger (Searston Formation) units.
AGE JUSTIFICATION:	Shelly fauna (Bell, 1948), Knight, 1983), conodonts (von Bitter and Plint-Geberl, 1982) and spores (Knight, 1983). The fossils compare to those found within subzones D and the lower part of E from rocks of the Windsor Group of Nova Scotia.
HISTORY:	This formation was first described as division C of the Windsor Marine Series by Murray in 1873 (in Murray and Howley, 1881). Later, Hayes and Johnson (1938) informally assigned lower and upper beds to the Woody Point shales and sandstones respectively. The same divisions were called the Woody Cove and Woody Head Beds by Bell (1948). Baird and Cote (1964) placed the same rocks in the upper Codroy.
REFERENCES:	Knight, (1983), Murray and Howley (1881), Hayes and Johnson (1938), Bell (1948), Baird and Cote (1964).

Appendix B - Summary of Evidence supporting hypothesis that the Long Range fault formed the southeast margin of the Bay St. George subbasin

1. Anguille Group

A. Strata belonging to the Spout Falls Formation are known to pass from sandstones in the Anguille Mountain area to sandstones, pebbly sandstones and some conglomerates in the Bald Mountain area i.e. approaching fault. Thick bedded conglomerates are found in topmost Anguille Strata along Crabbes River near fault itself.

B. Conglomerates and arkosic grits in the Friars Cove Formation on Codroy Island have perthetic feldspars and granitic detritus which compares favourably with granitic rocks intruding the crystalline terrain of the Long Range Mountains (Chorlton, personnel communication 1981).

C. Brown (1977) believed that the palaeo-Long Range Mountains were an uplifted terrain during the deposition of the Windsor Point Group that lies along the Cape Ray Fault. This group is of Devonian age and contains conglomerates rich in clasts of Long Range gneiss which underlay the Long Range Mountains between the Cape Ray and Long Range faults.

2. Codroy Group

A. Presence of conglomertes and pebbly sandstones in the Mollichignick and Overfall Brook Members of the Robinsons River Formation in close proximity to and against the Long Range Fault.

B. Pebbles and sand grains in both units compare closely with rock types known to underlie the Long Range Mountains directly south-east of the subbasin.

C. There is a marginward coarsening of detritus and a overall change of lithofacies mapped towards the Long Range Fault in the Mollichignick Member. The facies changes include lacustrine and floodplain siltstones intercalated with sheet sandstones and only minor conglomerate deposited by flashflood generated ephemeral and braided streams in basinal position passing marginward into dominantly conglomerates and pebbly sandstones deposited on alluvial fans.

Detritus and crossbedding in sandstones of the Overfall Brook Member fully support a southeastern derivation of the strata in the member.

D. Conglomerates occur in undivided red strata belonging to the Codroy Group along Crabbes River. This suggests that floodplain siltstones and sandstones that make up the Codroy Group succession along the present coastline of St. Georges Bay pass southeastward into a conglomeratic facies.

E. The Brow Pond lentil composed of pebbly arkosic sandstones and cobble and large pebble conglomerates occurs in the northeast corner of the subbasin. Some if not all of these strata appear to underlie the Barachois Group and hence are included in the Codroy Group. An unconformity in the lentil indicates active uplift occurring nearby during the deposition of the lentil. One margin of the lentil abuts the Long Range Fault. The presence of clasts and detritus very similiar to rocks of the Topsails Igneous Complex and other Lower Paleozoic crystalline and volcanic rocks confirm a detrital source in the immediate vicinity of Central Newfoundland.

Strata belonging either to the Codroy or Barachois Group

Perhaps the best evidence that the Long Range Fault and the geologic terrain to the southeast formed the subbasin margin and mountain terrain and source is found in cliff exposures near Trainvain Brook, Codroy Valley. These rocks of unknown age are presently assigned to the Barachois Group (see also Belt, 1968, 1969) but might as likely belong to the Codroy Group. They consist of coarse fanglomerate deposits that lie with angular unconformity upon metagabbros of the Long Range ultramafic and mafic complex of Brown (1976, 1977). The conglomerates are full of cobble size, mafic, tonalitic and granitic rock fragments as well as sand detritus with an abundant distinct heavy mineral suite (see Knight 1983, page 268). that compares well to such mineralogy of crystalline rocks of the immediate area of the southern Long Range Mountains (Chorlton, personal communication, 1981).

The Trainvain Brook conglomerates deposited on an alluvial fan and including debris flow and proximal stream gravels are the only Carboniferous rocks known to be southeast of the present trace of the Long Range Fault. The succession shows rapid upward and basin ward fining of sediment indicating a narrow development of the fanglomerate deposits.

Conclusions

The evidence outlined points to a long history of activity upon the Long Range Fault during the Carboniferous so that A) source mountain terrain was maintained to the southeast B) the basin margin lay close to or in the near proximity to the fault and C) that the subsidence upon the fault accommodated the great thickness of Carboniferous strata that now constitute the subbasin. The evidence is presently weakest in the Anguille Group but strong evidence is afforded by rocks of the Codroy Group and possibly younger strata that the fault played a fundamental role in the historic development of the subbasin.

Appendix C - Discussion of formation and evolution of the Bay St. George subbasin - pullapart vs simple rift graben

In the main text of the thesis; two hypotheses are unevenly presented to explain the formation and evolution of Early Carboniferous strata of the Bay St. George subbasin. They are briefly summarized.

Model 1. A narrow pull-apart basin controlled by dextral wrench movements upon the Cabot Fault system and filled by strata of the Anguille Group followed by dominantly vertical movements during final stages of strike slip motion when a broader basin evolved and was filled by strata of the Codroy Group.

Model 2. The formation of a narrow rift graben between uplifting, horst blocks filled by sediments of the Anguille Group with subsequent development, possibly controlled in part by some strike slip movements, of a broader primary basin composed of many smaller depositories separated by archs and filled by sediments of the Codroy Group. A Devonian foreland basin may have preceded the formation of the graben

The first hypothesis has already been outlined in detail in the main text and is not treated further here. The second model only received scant treatment and is elaborated further below. Discussion of the merits of the two theories then follows.

The second hypothesis possibly evolved in the following manner. The event began with consolidation of the Appalachian fold belt in Newfoundland following the Acadian orogeny which included widespread granitic intrusion during the Devonian. Uplift of central Newfoundland occurred as the thickened crust adjusted isostatically and in response to final compressive stresses. Depressions within and adjacent to the mountain chain became the site of piedmont red bed deposition peripheral to central Newfoundland in the Devonian. One such successor basin occurred in western Newfoundland and probably formed an extensive low area underlying the Gulf of St. Lawrence and St. Georges Bay. This low may have included the present day Port au Port Peninsula and extended out beneath the Gulf of St. Lawrence (Haworth et al., 1976). Into this successor basin, red beds of late-Silurian early-Devonian age, the Clam Bank Formation, were perhaps first deposited. The Clam Bank Formation on the Port au Port Peninsula contains no evidence of a source from the Cambro-Ordovician platformal rocks (Rodgers, 1965, O'Brien, 1975) even though crossbeds indicate a westward palaeo-flow (H. Williams, pers. comm., 1979). O'Brien (1975) does, however, describe detritus, including chromite sand grains, derived from granitic and ophiolitic terrains. This evidence suggests a source in part in the Humber Arm allochthon and perhaps further east in central Newfoundland. Molasse sedimentation possibly continued throughout the Devonian, the youngest sediments being those of the Kennels Brook Formation. These are known from the Union-Brinex well (1973) in the Anguille Mountains to be greater than 2500 thick with no basement reached. Composition of detritus in the formation is also consistent with a source in central Newfoundland and lacks evidence of erosion of Cambro-Ordovician platformal strata. This perhaps suggests that an extensive alluvial blanket built westward across this successor basin. The blanket included lithofacies of both braided and meandering river systems deposited in a semi-arid climate. The eastern margin of the basin coincided probably with either the Long Range or Cape Ray Faults. These were probably active during this Devonian event as suggested by deformed, Devonian volcanic and sedimentary strata of the Windsor Point Group that are extensively developed along the Cape Ray Fault (Brown, 1977; Chorlton, 1979; Chorlton and Dingwell, 1981; Kean and Jayasinghe, 1981).

Following the westward progradation of these Devonian sediments however, the depositional setting changed with the formation of a narrow, fault-bound sedimentary basin surrounded by uplifting mountain chains to the north and southeast. In this narrow basin, sediments of the Snakes Bight, Friars Cove and Spout Falls Formation were deposited. The narrow basin formed along the trace of a major fault zone, located between the Long Range Fault and the southern margin of the western platform of the Appalachian orogen. The basin was approximatley 30 km wide and more than 125 km long. Bounding faults such as the Long Range Fault, growth faults within the basin, such as the Snakes Bight Fault, and other faults beneath St. Georges Bay and adjacent to the Steel Mountain anorthosite body were primary controls in the geological development of the basin at this stage. Most of these faults trend northeast.

The narrow, elongate basin formed as uplift of mountains continued southeast of the Long Range Fault and occurred for the first time, northwest of the basin. The latter probably formed when a fault-bounded horst of PreCambrian basement rocks beneath St. Georges Bay and the Port au Port Peninsula was uplifted, arching overlying early Paleozoic platformal and transported sedimentary rocks and the Devonian molasse. Cobbles and large pebbles derived by Carboniferous erosion of Cambro-Ordovician platformal and ophiolitic rocks occur in a conglomerate at the base of the Friars Cove Formation at Cape Anguille in the southwest of the subbasin. These conglomerates were derived from north of the subbasin and, in accordance with this hypothesis, suggest that Cambro-Ordovician platformal sediments and rocks of the Humber Arm allochthon were geographically distributed (and perhaps still are but are now under Carboniferous cover) throughout the present area covered by St. Georges Bay. Tilting of the Clam Bank Formation near Lourdes on the Port au Port Peninsula possibly occurred during this uplift. The uplift was likely gradual at first with denudation of the Devonian molasse which was probably only poorly consolidated and any underlying sedimentary rocks of the Humber Arm allochthon.

The influx of widespread conglomerates rich in carbonate, quartzite and granitic pebbles derived from Cambro-Ordovician platformal strata and underlying Pre-Cambrian basement indicates rapid uplift of the horst occurred prior to the deposition of the basal strata of the Friars Cove Formation. No further uplift followed but rather the upland was gradually reduced in elevation and areal extent. The southeastern margin of this west-trending mountain ridge lay close to a fault that is postulated to strike southeast beneath St. Georges Bay from the vicinity of but south of the Flat Bay anticline (Fig. 15). The mountain front retreated northwards as pedimentation and erosional processes attacked the mountain chain under semi-arid conditions. Consequently, by the commencement of deposition of the younger Codroy Group, the mountains were reduced to a relatively, low-lying ridge, on-lapped by flat-lying, thin, Codroy Group strata (see Romaines Brook).

Within the basin, considerable thickening of the succession southwestward across the Snakes Bight Fault suggests this was an active growth fault within the basin. The basin axis was located along the present core of the Anguille Anticline. Subsidence along the axis was greatest in the northeast in the vicinity of the north closure of the anticline where the succession is thickest.

The formation of the elongate fault-bound basin fundamentally altered the drainage pattern of the area. The extensive westward sloping alluvial plain of the early Devonian event was replaced by an inland drainage basin. Lacustrine conditions were rapidly established in the basin supplied by rivers draining from central Newfoundland and uplands to the north. The steep sided lake was initially filled by a deep water lacustrine sequence, the Snakes Bight Formation. The lake rapidly shallowed as sandy deltas encroached along the basin margins and axis. Sand-dominated deltas built an extensive delta plain on which marsh, shallow lacustrine and fluvial subenvironments flourished during the deposition of Friars Cove Formation. Deltaic-shallow lacustrine conditions persisted in the southwest of the basin until the close of the Anguille Group. However, in the northeast, alluvial red beds and fanglomerates were deposited forming the Spout Falls Formation.

The tectonic setting of the subbasin during the deposition of the Codroy Group was somewhat different. The main axis of the subbasin appears to have shifted northwestward from the axial locus of the Anguille Group to lay beneath St. Georges Bay. This may partly reflect present day outcrop patterns. It is however, supported by the available thickness, geophysical (fig. 38) and facies distribution data which suggest the axis coincided with the area now beneath St. Georges Bay. Sediments at least 5000 m thick were laid down in this trough. Northeast-trending faults were probably active, controlling influences in the distribution of sediments. Positive areas, some exposed in the early history of the group, e.g. Indian Head inlier, but most covered by the lower Codroy formations, as in the 'Flat Bay divide' (now Flat Bay anticline) and possibly the Anguille Mountains, separated this main basin from other smaller depositories to the southeast. An important trough lay east and southeast of the Flat Bay anticline during deposition of the lower Robinsons River Formation and probably also in the Codroy Road Formation. The 2700+ m of upper Codroy strata in the Codroy Lowlands also suggests a second trough formed southeast of the 'Anguille Mountain high' during the Mollichignick Member. The overall width of the active Bay St. George subbasin expanded from 30 km in the Anguille Group to at least 45 to 60 km in the Codroy Group. Its shape however, was no longer a simple linear basin but rather had a complex configuration of highs and lows (fig. 38). Presence of much thicker successions in different areas of the subbasin and at separate stratigraphic intervals e.g. saline sinks at base of Jeffreys Village Member and the pebbly sandstone-filled trough northwest of Flat Bay in the Highlands Member, suggests that fault movements initiated subsidence in separate areas at different times. The southeastern margin of the subbasin lay along or just southeast of the Long Range Fault. Alluvial fans and other deposits plus lithoclasts derived from the metamorphic, and crystalline rocks to the southeast testify that the fault was repeatedly active throughout the depositional history of the Codroy Group. Such a complex basin of highs and lows may have formed in response to strike slip movements upon the main faults within and bounding the subbasin.

Discussion

Examining these two hypotheses, the major contrast is found in the explanation of basin evolution during the deposition of the Anguille Group. The wrench fault model fits the evidence from the Codroy Group and is suggested in both models. The only difference is a question of timing, the wrench movements were coming to a end in the pure wrench fault model whereas they occur for the first time during deposition of the Codroy Group in the second model. Further discussion hence centers upon the evidence contributed by rocks of the Anguille Group.

In the following discussion, understanding of the geologic history of the sedimentary succession and the surrounding uplands is aided by the basal limestones (Ship Cove Formation) of the Codroy Group which is believed to be both a rock and chronostratigraphic marker. This is supported by the consistent lithological and biostratigraphic character of the formation in the Bay St. George subbasin and its correlative, the Macumber Formation, in much of Nova Scotia.

The discussion hinges essentially upon a number of points.

A. The significance in the Anguille Group of boulder and cobble-bearing conglomerates derived from Cambro-Ordovician platformal and ophiolitic strata.

B. Whether such Cambro-Ordovician Strata once underlay the area beneath St. Georges Bay and was completely removed by Carboniferous erosion or whether these uplands moved north-eastward away from the basin during deposition of the Anguille Group.

C. The distribution and explanation of sediments deposited within the subbasin. Kennels Brook Formation strata is conformable beneath the Snakes Bight Formation and is 3500 m thick in the southwest of the subbasin. Strata, 3500 m thick belonging to the Friars Cove and Spout Falls Formations conformably overlie the Snakes Bight Formation and dominate the succession in the northeast of the Anguille Mountains. Marine and non-marine rocks of the Codroy Group 3000 m thick and resting conformably upon the Anguille Group occupy a basin fill beneath St. Georges Bay lowlands and St. Georges Bay.

D. Growth faults such as the Snakes Bight fault controlled location of basin axis to the axial zone of the Anguille anticline.

E. There is a great thickness difference between conglomeratic rocks of the Fischells Conglomerate member at Flat Bay and the more than 6000 m of strata of the Anguille Group found in the axis of the subbasin.

Discussion of point A - The presence of conglomerates of proximal aspect (see pages 117-118) containing Cambro-Ordovician platformal and ophiolitic detritus within the Anguille Group is important because it shows an upland source must have formed north of the subbasin. The absence of such clasts in conglomerates of the Kennels Brook Formation suggests it may not have existed in the earliest history of the basin fill. The uplift of the northern highland is however believed to be the controlling tectonic influence that initiated the formation of a deep lake in which the Snakes Bight Formation formed.

The conglomerates are of two ages. The oldest ones form the base of the Friars Cove Formation throughout the northwestern limb of the Anguille anticline, the youngest form a 150 m thick succession in the Flat Bay anticline. These rest unconformably upon Grenvillian basement rocks and are conformably overlain by basal limestones of the Ship Cove Formation, hence it was deposited in the last phases of the Anguille Group and is believed to be laterally equivalent of top most strata of the Spout Falls Formation.

In both conglomerates the clasts derived from the platformal rocks resemble undeformed sediments such as found in the autochthonous Cambro-Ordovician rocks of western Newfoundland. This is important since these autochthonous sediments usually pass eastward structurally into parautochthonous, variably metamorphosed equivalents (Knight, personal observations, and also see Knight, Current Research, Newfoundland Department of Mines and Energy, 1980). In the Flat Bay area, boulders of black,oolitic and oncolitic grainstone resemble rocks of the Forteau Formation and white quartz arenites(quartzites) derived from the Hawke Bay Formation are very common in the conglomerates. The significance of this last observation of the undeformed nature of the clasts has relevance in discussion of point B. Clearly however, undeformed platformal rocks lay close to the southwest part of the subbasin during the deposition of the Friars Cove Formation. This means that either an upland of such rocks was present in the area but was eroded away prior to deposition of the Codroy Group or that it has moved northeastward in response to dextral wrench movements. The latter is preferred because of points discussed under point B.

Discussion of point B - Did or do Cambro-Ordovician platformal rocks underlie the water and/or Carboniferous cover rocks beneath St. Georges Bay? If so what kind would they be? Answering the latter question first - it is likely that this zone by comparison to the pattern of distribution of western Newfoundland geologic terrains would have contained uplands formed of thrust slices of deformed and low grade metamorphosed carbonates and siliclastics. This is particularly probable since ophiolitic clasts in the conglomerates suggest ophiolitic sequences would also be present. The pebbles in the conglomerates however suggest undeformed autochthonous rocks occurred close to the subbasin during the accumulation of the basin fill. Aeromagnetic maps suggest PreCambrian basement rocks underlie the northern part of St. Georges Bay and the Bay St. George subbasin. This is supported by such basement rocks outcropping at Indian Head, in the core of the Flat Bay anticline, at Mt. Howley and beneath basal limestones and evaporites of the Codroy Group at Romaines Brook (McKillop, 1955, 1959). Nowhere do platformal rocks occur within the borders of the basin. This might be explained if the Cambro-Ordovician strata was completely eroded away and dumped in the basin during the deposition of the Anguille Group but prior to deposition of the Codroy Group. Evidence such as regularly or at least sparcely intercalated conglomerates containing Cambro-Ordovician detritus in the Friars Cove and Spout Falls Formation has not been found to support this explanation.

Is there an alternative? It is believed that basin pullapart coupled with northeastward motion of the upland solves this problem and also explains the location, composition and texture of the conglomerates. A wrench model also overcomes the problem that the present trend of the autochthon as interpreted from geophysical studies (Haworth, 1975a) is westward from the Port au Port Peninsula across the Gulf of St. Lawrence and not southwestward towards the northwest margin of the subbasin.

Discussion of point C - as pointed out in the text (pages 121 and 368-371) three basinfills of approximately 3500 m thickness occurred in order of the oldest in the southwest and youngest in the northeast. No unconformities separate these three sequences so that more than 9000 m of sediment accumulated in the basin over a time frame of perhaps 20 million years. The basin fills are all apparently deformed by the same phase of deformation. In a simple rift graben with generally uniform subsidence this would be an exceptionally thick succession.

Tilting of fault blocks within the basin could explain the shifting locus of deposition but the sequential order is best explained if a pullapart trough developed as discussed in the main text. The fact that the basin was extending and not affected by compression allowed for the conformable succession. (This is in marked contrast to synchronous events that unfolded in the evolution of the Deer Lake Basin to the northeast of the Bay St. George subbasin. There rocks of the Anguille Group were highly deformed and eroded prior to deposition of the Deer Lake Group which is known to be time equivalent of much of the Codroy Group).

Points D and E can be explained readily by either model. However, they both fit the picture expected in an active strike slip basin of rapid variations in thickness over short distances associated with active border or in basin faults.

An example of one such thick basin fill that is best explained within the pullapart model includes the formation and filling of a depository in the present area of St. Georges Bay. Here 5000 m of Codroy Group and possibly younger strata were deposited in an area that was an upland during the deposition of the Anguille Group. The succession includes thick evaporite sections. This suggests that the marine strata of the lower Codroy Group was deposited in the trough suggesting the early formation of the depository after the geologic events that influenced the deposition of the Anguille Group were completed.

Other points that support a strike slip basin model are

1. similar tectonic setting for many other Carboniferous basins in Newfoundland and Maritime Canada.(Bradley, 1982)

2. Deformation of the rocks of the Bay St. George subbasin is interpreted as the product of right lateral strike slip movements.(Knight, 1983)

3. Some of the major northeast trending faults cutting the Cambro-Ordovician platform display evidence of some right lateral strike slip motion (Knight personal observation). These faults which penetrate both Paleozoic cover and PreCambrian basement have at least Acadian movements. However, some faults also affect Carboniferous rocks along the north of the Bay St. George subbasin and must by inference include Carboniferous movements.

Appendix D - Description of Sections in the Anguille Group

Section - Snakes Bight Formation

UNIT NO	DESCRIPTION	UNIT THICKNESS IN METERS	TOTAL THICKNESS IN METERS
	Location: Hynes Gulch, commencing about 2 km upstream from coast. Base placed at lowest black shale unit overlying some 59 m of green-gray, very fine sandstone and siltstone of the top of the Kennels Brook Formation; basal contact not well exposed. Upper contact placed at base of conglomerate and pebbly sandstone sequence of Friars Cove Formation which is located nearly 1.2 km upstream from shore.		
73	Covered interval to basal conglomerate of Friars Cove Formation; likely of sandstone	6.20	785.56
72	Gray sandstone; fine to medium grained; crossbedded, 10-15 cm thick sets; 15-45 cm beds of planar thin bedding and lamination; 15-20 cm beds of planar, thin bedded, very fine sandstone and shale near base of unit; planar bedding planes with current markings common on bases.	16.67	779.36
71	Thick bedded gray sandstones (units 70 to 384 cm thick alternating with shales and thin sandstones in units 23 to 158 cm thick: Thick bedded sandstones consist of beds averaging 40 to 70 cm thick, graded medium to medium-fine grained, with planar bases carrying some current markings; Flutes with directions 220 to 241; internal structure of beds - massive grading up to laminated,		

	some cross beds near top of beds, grading into shale or laminated mudstsone into beds; upper bedding plane commonly deformed. Shale plus thin sandstone beds consist of black shale plus 1-3 cm flat planar bedded, very fine sandstones or coarse silt-stones, these are laminated or ripple cross laminated; beds often lenticular	9.80	762.69
70	Gray sandstone; 40-60 cm beds, planar bedding planes, some flute and groove casts directions 242 to 261, massive; interbedded with 5-15 cm beds of interbedded shale and thin bedded, laminated very fine sandstone	9.09	752.89
69	Gray shale with 1/2 to 1 cm laminated siltstone beds and a few, 3 to 20 cm, planar bedded fine sandstone beds.	2.05	743.80
68	Gray sandstone; very fine to fine grained; 10-25 cm beds, planar base with some current markings and flutes; internally massive and laminated; shale partings between beds.	5.60	741.75
67	Black shale; interbedded at intervals after basal 11 m with single beds of 65-70 cm thick of very fine to fine, gray sandstone rich in mudclasts, flutes on base; massive, local crossbeds; grading up into shales. Black shales have ferruginous dolomitic and gray siltstone laminae and thin beds which increase in quantity below thicker sandstone beds. Sedimentary faults, synaeresis cracks.	28.68	736.15
66	Gray sandstones interbedded with shales: sandstone beds 16 to 80 cm thick; at first medium to fine grained		

	graded, includes complete Bouma sequence massive with mudflakes at base, laminated overlain by cross lamination which is commonly deformed passing up into convoluted laminated siltstone which is capped by shale; flutes at base of some beds direction 229, some thin sandstone beds with no shale interbeds, generally planar bedded, laminated or may be completely of ripple drift. Shales between most sandstone beds 20-60 cm thick; contain some sandstone laminae and lenses. Sandstones at top 185 cm of unit become finer grained and only 5 to 35 cm thick, consisting mostly of lamination and thin flat bedding	16.50	707.47
65	Mostly covered; probably shale	4.20	690.97
64	Poorly exposed, sandstones	1.75	686.77
63	Black shale	4.20	685.02
62	Gray sandstones interbedded with shales: Sandstones except in top 175 cm consist of 60-80 cm thick beds; mostly fine grained, massive internally but for some color variations; flutes and grooves on planar bases, direction 007/187; upper 175 cm consists of 35 cm sandstone beds alternating with shale and grading up into overlying unit.	21.58	680.82
61	Gray sandstone with thin shale interbeds or partings: sandstones 10-15 cm thick; medium to fine grained; massive; some are lenticular thin bedded sandstones in thicker shales	1.24	659.23
60	Gray sandstone; fine grained;		

	100 cm beds; massive with a few laminations at top of beds	2.05	657.99
59	Gray sandstones: poorly exposed; in lower half sandstones mostly 40 cm thick; massive and many with lamination and planar thin bedding; interbedded with 5-10 cm thick shales with thin sandstones at intervals; grit and pebbly grit 53 cm thick within thick sandstone beds scour base, massive with vague layering at top, sits on 40 cm cross-bedded sandstone: bedded sandstone-shale only in upper part of unit.	16.80	655.94
58	Gray sandstone; 40-60 cm beds, graded, massive to laminated, with convolution, shale partings	1.40	639.14
57	Cover	4.37	637.74
56	Black shale with thin planar beds of laminated siltstone, very fine sandstone and ferruginous dolomite	4.20	633.37
55	Cover	11.20	629.17
54	Sandstone: very fine grained; 45 cm beds massive and laminated	2.00	617.97
53	Sandstone: graded beds of very coarse to coarse grained in lower 16 m and coarse to medium grained in upper 9 m; Beds 30 to 40 cm thick, planar bases with flute, groove and load casts, directions, 185° to 230°; internally massive. Inter-bedded with some 10-20 cm beds of shale and thin bedded, laminated medium to fine sand-stone, some with basal current		

	hieroglyphs	24.50	615.97
52	Sandstone interbedded with siltstone and shale; sandstones 10-15 cm thick, very fine grained grading to shaly, very fine grained; planar top and base with some flute casts; internally rich in planar lamination and ripple drift, often highly convoluted including isoclinal flat-lying folds, pseudonodules and boudinage of bedding; shale partings or beds 1-15 cm thick of thin bedded intercalated laminated siltstone and shale. Towards base very fine grained sandstones mostly 20 cm thick with grading and internal structure including Bouma divisions A and B, commonly deformed and intercalated with 15 cm shales	6.04	591.47
51	Gray sandstone: thick bedded, 60 cm thick, coarse to medium grained with small white quartz pebbles and shale intraclasts; large mudclasts 20 cm long at base near base of unit; beds internally massive with vague lamination near top of beds picked out by color variation	7.25	585.43
50	Conglomerate and pebbly, gritty sandstones: Conglomerate 70 cm thick at top, composed of white and reddish quartz pebbles up to 6 cm size; shale and laminated or structureless dolomite intraclasts up to 10 cm in size, crudely graded; internally massive; erosive base. Pebbly and gritty, coarse to very coarse sandstones, 44 to 66 cm thick, with similar lithoclasts, scour bases and some flutes, internally massive. Bed, 36 cm thick,		

	of wavy laminated silt-stone between conglomerate and sandstones	2.16	578.18
49	Interbedded sandstone-siltstone and shale: Beds, 10-20 cm, of planar bedded, laminated coarse siltstone or very fine sandstone alternating with 2-5 cm shale or 5-10 cm beds of inter-laminated shale and sandstones. Some beds completely convoluted.	5.57	576.02
48	Sandstone: Thick bedded, 40 cm thick, internally massive	1.37	570.45
47	Sandstone-siltstone-dolomite-shale: Planar thin bedded, 1-3 cm thick, laminated very fine sandsstones, coarse siltstone or dolomite beds with shale laminae and thin shale interbeds. Some 15-25 cm graded, very fine sand-stone to coarse silt-stone; flute and load casts on base; internally structureless.	11.78	569.08
46	Sandstone: gray; fine to medium grained, thick bedded, 20-60 cm thick, separated by 1-3 cm black shales; planar bases with flutes and groove casts; internally massive, some crossbedding.	8.36	557.30
45	Sandstone-siltstone and shale: very fine sand-stone and coarse silt-stone beds, 15 cm thick rusty weathering, planar bedded, internally laminated; alternating with 20 cm beds of inter-calated thin bedded sand-stone, siltstone and black		

	shale	9.96	548.94
44	Sandstones interbedded with intercalated shale and thin bedded sandstones: Sandstones, thick bedded, 40-50 cm thick, massive, internally convoluted, basal flutes, load casts and local erosive bases; alternating with 20 cm of shale with sandstone laminae. Shale and thin bedded sandstones compose basal 2.1 m of unit.	7.97	538.98
43	Black shales with sandstone laminae, thin beds and 15 cm beds arranged in two coarsening upward sequences, 5.37 and 7.87 m thick. Sequences commence with black shales with sandstone and siltstone laminae, overlain by regular bedded, sandstone grading into black shale each 15 cm thick capped by thicker bedded, 40-50 cm sandstone beds. The sandstones are mostly internally laminated and crosslaminated with convolution, some basal flute casts; direction 225°.	13.24	531.01
42	Black shale with sandstone arranged in two coarsening upward sequences 5.13 and 1.13 m thick. Shales with thin beds of laminated, gray siltstone and/or very fine sandstone; pass up into 10-25 cm laminated and cross laminated, very fine sandstones which include Bouma division A and B. Boudinage and sedimentary deformation common.	8.26	517.77
41	Sandstones separated by 1-2 cm shales; sandstones 5-15 cm thick and locally reach 30 cm in middle of unit; dominantly planar bedded, internally		

	laminated and much convolution	6.28	509.51
40	Black shale with laminae and 1 cm beds of sandstone, siltstone and ferruginous dolomite, two isolated beds, 35 cm thick of massive sandstone	27.44	503.23
39	Sandstone: gray, medium to fine grained; erosive base, Bouma divisions A and B.	0.95	475.79
38	Sandstone and shale: rusty weathering, very fine sandstone beds 15 cm thick separated by shale partings	2.77	474.84
37	Sandstone: gray; thick bedded, 60-100 cm thick; coarse grading to fine grained; Bouma divisions A, B, C capped by 10 cm shales; mudclasts at base of beds above planar bases with flute and load casts, direction 175; Sandstone beds appear to thicken upwards in unit	15.68	472.07
36	Shale: black and some gray; some sandstone laminae and single 10 cm sandstone bed in shales; some 15 cm sandstone beds immediately below overlying unit. Lower 10 m is poorly exposed	20.18	456.39
35	Sandstone interbedded with interbedded shale and sandstone; sandstones are 30-200 cm beds thickness increasing upwards; fine-medium grained, massive; intercalated with 30 cm beds of shale with laminae or thin beds of laminated sandstone	9.09	436.21
34	Sandstone: poorly exposed; appears to be mostly thick beds up to 80 cm thick;		

	enclosing mudclasts and having flute and load casts on bases	11.89	427.12
33	Black shale with laminae and thin beds of sandstone and siltstone; 32 cm sandstone near top	1.29	415.23
32	Sandstone: gray; 10-40 cm beds separated by 1 cm black shale; fine and medium grained; planar and erosive bases, flute casts; mostly graded massive beds, some internal structures deformed; some 15-30 cm beds of shale with thin sandstone	25.13	413.94
31	Black shale with ferruginous dolomite annd some sandstone laminae and thin beds; two 25 cm sandstone beds near top; generally poorly exposed	13.29	388.81
30	Sandstone: gray; 10-45 cm beds separated by 1-2 cm black shales; erosive to planar, fluted bases; internally mostly structureless	20.28	375.52
29	Poor exposure: includes some 40 cm sandstone beds separated by 25-30 cm of black shales and thin sandstone beds	5.57	355.24
28	Sandstone: gray; micaceous; 15 to 70 cm thick; planar bases; medium and some coarse grained; locally rich in black shale intraclasts; internally massive; scour, planar and fluted bases; 1 to 3 cm shale interbeds; two 50 cm beds of black shale with thin bedded, laminated (locally deformed) sandstones at 11 and 24 m from base	30.06	349.67

27	Cover-probable shale with thin sandstones	4.88	319.61
26	Black shale with ferruginous dolomite laminae and laminae and 1-5 cm thin planar beds of laminated sandstone; two sandstone beds, 35 cm thick near top	6.27	314.73
25	Sandstone: gray; 15-40 cm beds separated by thin shales; apparently mostly structureless; monotonous bedding except for some 1 to 1.5 m sequences of 15 cm sandstones interbedded with 15 cm of shale	65.06	308.46
24	Sandstone and shale: rusty weathering, gray, very fine sandstones 5-15 cm thick separated by 5-10 cm shales; deformation	7.69	243.40
23	Black shale with laminae of ferruginous dolomite and siltstone and sandstone	5.59	235.71
22	Sandstone and shale: sandstones, 10-40 cm thick, medium grained; apparently structureless, separated by 15 cm shales	10.48	230.12
21	Black shale with 5 cm planar bedded, rusty weathering siltstone; plant fragments	3.14	219.64
20	Sandstone: gray: 45 cm thick beds, separated by thin black shales	7.69	216.50
19	Black shale with 5 cm, rusty weathering planar bedded siltstone	0.67	208.81
18	Sandstones: gray: medium grained near base but very coarse and coarse grained locally grading to medium in upper 7 m; thick bedded 45-65 cm thick beds separated by no or 2 cm		

	shales; planar, fluted bases; internally structureless; separated at three intervals by 46-139 cm beds of shale with thin planar bedded sandstones and laminated siltstone	18.09	108.14
17	Covered interval: bedded sandstone near top, shale near base	23.01	190.05
16	Sandstone and shale; gray sandstone, bedded, 15-40 cm separated by up to 15 cm of shale; medium coarse grading to fine grained; mostly massive but some beds in lower sequence include massive overlain by lamination and cross lamination. Two sequences 16.98 and 20.37 cm thick separated by 55 cm of black shale with 3 cm beds of laminated sandstone and shale	37.90	167.04
15	Cover; possibly black shale	3.61	129.14
14	Black shale with thin, laminated sandstones; slump folds and rolled sandstone masses in shale	11.54	125.53
13	Sandstone: brown weathering gray; highly deformed with bedding destroyed	2.66	113.99
12	Black shale with ferruginous dolomite and some sandstone laminae, small sedimentary faults and isoclinal slump folds	1.35	111.33
11	Sandstone and shale; gray sandstone; 30 cm thick interbedded with 5 cm black shales; sandstone coarse grading to fine grained; undulose and deformed bases, shale		

	intraclasts at base; internally structureless	10.81	109.98
10	Black shale with ferruginous dolomite laminae	2.70	99.17
9	Sandstones and shales; well bedded, not well exposed	10.99	96.47
8	Black shale and very fine dolomite laminae	1.91	85.48
7	Sandstone and shales: sandstones, 10 cm-40 thick, medium grained, structureless; shales up to 10 cm thick; amalgamated beds? up to 2.5 m thick of sandstone in middle of sequence	31.78	83.57
6	Sandstone; gray, medium grained, 10-40 cm beds, massive, minor shale interbeds	4.90	51.79
5	Black shale with dolomite laminae and 5 cm sandstone beds	12.56	46.89
4	Sandstone: gray, coarse grained, 30 cm beds in two sequences 80 and 210 cm thick separated by 60 cm of black shale with thin sandstone	3.50	34.33
3	Black shale, poorly exposed	5.88	30.83
2	Sandstone; poorly exposed	4.88	25.25
1	Black shale with yellow weathering dolomite laminae; slump breccias of shale and dolomite; convolute bedding; passing down into black shale alone	20.37	20.37
	Base is not well exposed and overlies 60 m of poorly exposed, bedded gray, very fine sandstone and siltstone of the Kennels Brook Formation at this interval.		

UNIT NO.	DESCRIPTION	UNIT THICKNESS IN METERS	TOTAL THICKNESS IN METERS
Section - Friars Cove Formation			
	Location: Friars Gulch commencing approximately 0.7 Km upstream from shore and continuing to mouth of brook on shores of Friars Cove. Base is placed above 7.78 m of planar thin bedded coarse sandstones which contain some small 2 cm rhyolite pebbles, and which overlies 12.98 m of medium grained arkosic sandstone overlying 7.98 m of laminated, siltstones and 1.86 m of black shales. Top is gradational and placed above last thick unit of gray sandsstone and shale and at base of first (>1 m thick) red sandstone.		
56	Sandstone: green gray, fine grained, micaceous and rich in carbonaceous plant debris, erosive base, cross bedded, cross-laminated and laminated, shale interbeds towards top	5.10	500.07
55	Gray shale	0.40	494.97
54	Sandstone: green-gray, medium to fine grained, arkosic, shale intra-clasts	20.22	494.57
53	Gray shale with some 10-20 cm thick laminated sand-stone beds near top (highly sheared)	3.30	474.35
52	Sandstone: green-gray and minor red, fine and some medium		

	grained, cross bedded and laminated; some 1-10 cm red shale interbeds	62.10	471.05
51	Covered interval	8.65	408.95
50	Sandstone and shalel: green, medium grained arkosic and green very fine grained micaceous sandstones in 30 cm beds, separated by 1-30 cm green shales; lamination and ripple drift common	23.79	400.30
49	Sandstone: green, medium grained, cross bedded, basal scour, overlain by red, laminated and ripple cross laminated very fine sandstone and coarse siltstone in two beds 204 and 84 cm thick.	2.88	376.51
48	Sandstone and shale: green arkosic sand-stones, fine to medium grained, 20-30 cm beds, planar lamination and ripple cross lamination, ripple marked tops to beds; red, shaley, laminated very fine sandstone in top 30 cm	1.85	373.63
47	Covered interval, appears to be 20-30 cm thick planar bedded, green, fine to medium grained, arkosic sandstones interbedded with green shales	13.21	371.78
46	Sandstone: gray, fine to very fine grained, bedded, laminatioon and cross beds, mud-cracks near base	7.64	358.57
45	Shale and thin sand-		

	stone and siltstone: shales intercalate with planar thin bedded, laminated, very fine, grained, sandstones for 100 cm then pass up into 2 cm planar bedded, laminated, rusty weathering siltstones	5.51	350.93
44	Sandstone: green gray, 20 cm b~ds, laminated and thin bedded	6.82	345.42
43	Sandstone: green, arkosic, medium grading up to fine grained, cross bedded and laminated; grading up to very fine grained, micaceous sandstone. Lamination and ripple cross lamination, plant fossils	6.46	338.60
42	Sandstone: green, arkosic, grading up into reddish-green, fine and very fine grained, micaceous sandstone and some siltstone; cross bedded and laminated especially near top.	10.00	332.14
41	Sandstone: green, fine grainedd grading up into red, very fine grained sandstone, internally laminated	3.35	322.14
40	Sandstone: green and red, mostly fine grained with some coarse sandstone in some beds, arkosic, internally laminated, thinly stratified and cross bedded; red sandstone in top 230 cm, finer grained, bioturbated and mud-cracked silt partings	16.98	318.79

39	Covered - shale probable	5.35	301.81
38	Shale and rippled thin bedded, very fine to fine grained sandstones	2.05	296.46
37	Sandstone: gray, fine grained, some coarse laminae, cross bedded and laminated, shale interbedded near top of unit	2.98	294.41
36	Gray shale	0.35	291.43
35	Sandstone and shale: gray, fine grained, sandstones, 20-30 cm beds rich in shale intraclasts, most structureless with some lamination, scour bases and others with flute casts; gray shale interbeds 5-10 cm thick	2.05	291.08
34	Shale and siltstone: gray shale with rusty weathering siltstone laminae and thin beds with some sandstone beds up to 35 cm thick near top	9.51	289.03
33	Sandstone and shale: green and minor red, arkosic, very fine to fine-medium grained, 30-70 cm beds, internally thinly stratified, laminated and cross bedded, green shale intraclasts common,, 10-20 cm green shale interbeds, mud-cracks, intraformational conglomerate at base of unit overlain by 3.7 m of crossbedded sandstone.	47.18	279.52
32	Shale and siltstone: green, shale overlain by red and green siltstone and very fine sandstone,		

	lamination, cross lamination and climbing ripple drift (type C)	0.97	232.34
31	Sandstone and shale: green, fine grained, 35 cm thick beds, some amalgamated, most separated by 5-35 cm of mudcracked green shale; sandstones show internal lamination, crossbedding and rib and furrow.	7.79	231.37
30	Sandstone and shale: sandstones 10-50 cm thick, planar bedded with internal lamination and some symmetrical ripple marks; intercalated with 10 to 100 cm of shale with sandstone laminae and thin beds	3.97	223.58
29	Sandstone: gray, fine grained, thin bedded and planar laminated siltstone interbeds at top, symmetrical ripple marks at top; crest direction 095, 025	1.42	219.61
28	Gray and black shale: 1-5 cm, rusty siltstone and sandstone beds near top and base composed either of undulose lamination often with load casts on bases or erosive bases, overlain by cross lamination; comminuted carbonaceous plant debris	5.75	218.19
27	Sandstone: gray, fine grained, internally thinly planar stratified and laminated with isolated cross beds; some mudcracks	1.97	212.44
26	Gray to black shales:		

	1-6 cm rusty weathering siltstone, undulose and planar beds, internally laminated only near base and top. Mudcracks common in upper 8 m	10.00	210.47
25	Gray shale and sandstone: Shales; 5 to 42 cm thick separated by 15-20 cm thick, very fine grained, structureless sandstones; load casts on bases	0.80	200.47
24	Sandstone and shale: gray, very fine and medium grained sandstone, planar and mudcracked bases, internally laminated; alternating with 1-3 cm and rarely 30-42 cm shales, plant rootlets and mudcrcks in shale.	1.58	199.67
23	Gray and black, shale, gray shale with some very fine sandstone beds and lenses 1 cm thick in lower 232 cm. Sandstones have erosive bases and planar top, brush marks, some large mudcracks. Overlain by black shale becoming gray in top 60 cm, only a few 1-3 cm thick, planar bedded argillaceous, very fine sandstones near top	6.56	198.09
22	Sandstone: gray, very fine grained, erosive base	0.98	191.53
21	Gray and black shale: with argillaceous very fine sandstones, 2-10 cm thick in basal half of unit, sandstones have erosive bases, flat		

	tops, load casts and flame structures, internally structureless overlain by lamination. Black carbonaceous coatings and abundant plant debris in shales and sandstones	4.60	190.55
20	Sandstone: gray, fine grained coarsening upward into pebbly and gritty medium-coarse sandstone, planar base for first 176 cm, overlain by thick bedded, (60-70 cm) massive grits intercalated with 20 cm laminated fine sandstones	6.96	185.95
19	Shale and thin bedded sandstones: sandstones 1-5 cm thick, fine and very fine grained, internally laminated, locally sandstones reach 40 cm near top; shale partings and beds up to 6 cm thick	2.08	178.99
18	Sandstone: gray, fine grained, 20-40 cm beds, internally planar stratified and laminated, some crossbeds poorly exposed	26.65	176.91
17	Black shale with light colored sandstone and siltstone laminae	2.60	150.26
16	Sandstone: brown weathering, gray, coarse and very fine grained, 20 cm beds internally laminated; thin shale interbeds	1.04	147.66
15	Sandstone: gray, fine grained, 30 cm beds, internally planar stratified, laminated and crossbedded	25.22	146.62

14	Pebbly grit grading up into gritty and pebbly medium grained arkosic sandstone; pebbles 3 cm diameter, bedded but internally structureless	2.29	121.40
13	Sandstone: gray, fine grained, structureless	1.93	119.11
12	Sandstone: gray, fine at first and coarsening to medium grained upwards, capped by pebble layer; internally planar stratified and cross bedded; pebbles up to 12 cm diameter of pink granite, white quartz and white quartzite.	20.24	117.18
11	Gray shale, with dolomite and siltstone laminae, top 45 cm covered	2.70	96.94
10	Sandstone: gray, arkosic, fine and medium grained thick bedded 20-60 cm, mostly structureless with some internal planar stratification	9.32	94.24
9	Sandstone and shale: sandstone in 15 cm beds alternating with 15 cm of thin 2 cm sandstone and siltstone beds	1.35	84.92
8	Sandstone: gray, arkosic, medium and coarse grained, mostly thick bedded, 80 cm beds, structureless, some thin shale interbeds.	5.00	83.57
7	Gray shale and thin silt-stones; siltstones have erosive bases and are internally laminated	1.69	78.57
6	Sandstone: gray, fine grained, 20 cm beds of planar stratifications, some ripple marks	23.87	76.88
5	Pebbly sandstone: gray,		

	coarse grained, massive, 8 cm pebbles of white quartz, K feldspar and red granite.	1.05	53.01
4	Sandstone: gray, arkosic, rich in pink feldspar and gray shale intraclasts layers; mostly massive, with some bedding near top where beds consist of massive interval overlain by planar stratification	5.99	51.96
3	Gray shale and sandstones: shale in beds 20-30 cm thick separated by 18-30 cm planar stratified and laminated sandstone. 103 cm of crossbedded and laminated, fine sandstone in middle of unit.	2.47	45.97
2	Sandstone: gray; medium grading up into fine sandstone; planar stratified and laminated with some cross beds	10.85	43.50
1	Gritty and pebbly sandstones plus conglomerate beds: Gray, arkosic grits and sandstones; very coarse to medium-coarse grained; generally poorly sorted, planar stratification and lamination to low angle inclined stratification and shallow erosional surfaces, stratification may be normally graded; locally contains, pebble layers of pebbles mostly 1/2-8 cm diameter, minor crossbeds; conglomerate layers have pebbles set in poorly sorted medium to very coarse sandstone; pebbles up to 22 cm diameter, crude stratification some conglomerates lie erosively and others gradationally in sandstone. Some grade		

up into sandstone. Conglomerates 6 to 84 cm thick. Pebbles of white quartzite, pink granite, white quartz, gray limestone, yellow weathering pale gray dolostone, porphyritic rhyolite	32.65	32.65

Section - Spout Falls Formation

UNIT NO.	DESCRIPTION	UNIT THICKNESS IN METERS	TOTAL THICKNESS IN METERS
	Location, Friars Cove, northeast shore from headland to top unit of Friars Cove type section situated at mouth of Friars Gulch		
36	Sandstone: red, fine to very fine grained, some green coarse grained sandstone, planar to scoopshaped basal scour; 30-60 cm beds, sheet and lenticular in shape. Scour or planar bases, cross beds, lamination and cross lamination; 40 cm beds of red siltstone with sandstone laminae and ripple cross lamination in middle of unit	5.70	254.07
35	Sandstone: green to reddish green, arkosic, coarse grained, planar stratification, lamination, some cross-beds towards top.	2.26	248.37
34	Sandstone: green, some red, arkosic, medium to coarse grained, erosional base above which occur mudclast rich sandstone; generally sandstone, 30 cm beds, planar base and top, internally planar stratified or laminated with parting lineation common in lower beds but absent at top where sandstone becomes very fine grained and red; some ripple cross lamination	3.42	246.11

33	Sandstone: green to red upwards, coarse to very fine grained, planar scour base overlain by planar thin stratification and lamination, some planar crossbeds and capped by fine lamination and some ripple drift. Red shale partings near base	1.70	242.69
32	Sandstone: green, broad curved scour base, outlined by gray shale intraclasts, internally planar thin stratification and lamination, some convolution	7.50	240.99
31	Sandstone, siltstone and shales: red some green, 30-40 cm beds, flat to crosscutting planar bases, overlain by green, laminated sandstone overlain by argillaceous, red, cross laminated very fine grained sandstone and siltstones; some bioturbation; red shale interbeds	2.80	233.49
30	Sandstone: green, arkosic and micaceous, medium to fine grained, scour base, crossbedded, 15 cm to 40 cm thick, and planar lamination, internal scours, parting lineation, plant fragments, bioturbation, red shale lenses.	5.22	230.69
29	Sandstone: green, coarse to medium grained, fining upwards, basal scour overlain by gray shale intraclasts, internally planar stratification with parting lineations, some isolated crossbeds, capped by 12 cm laminated shaley siltstone	6.22	225.47

28	Sandstone: gray, medium and some coarse grained, 10-80 cm beds; beds thicken upwards, separated by shale partings at first and 4-15 cm gray shales upwards. Beds composed either of large planar and trough crossbeds or of planar lamination with small mudflakes on laminae and rippled, mudcracked tops, some broad shallow, symmetrically filled channels, some bioturbation upwards	7.23	219.25
27	Sandstone: green, medium grained, 80 cm beds, broad elliptical scours filled by 10 cm thick trough cross beds, mud-cracked shale partings, between beds, some planar scours associated with planar crossbeds	2.00	212.02
26	Sandstone: green, arkosic, coarse grading to fine upwards, 40-60 cm beds, basal scours to beds, overlain by mudflakes and planar lamination with parting lineation, current direction 150-330, some load casts and convoluted lamination	5.20	210.02
25	Sandstone: green and gray, arkosic, mostly coarse grained but fine grained in middle 70 cm; sharp scour base to unit and to beds to give lenticular crosscutting beds especially in middle of unit. Green shale interbeds in upper half of unit. Sandstones mostly crossbedded, some		

	large, 24-40 cm thick, some planar lamination near top	5.20	204.82
24	Red mudstone	0.10	199.62
23	Sandstone: green and red, argillaceous and fine grained, large scours in the unit, overlain by planar lamination and ripple cross lamination, bio-turbation in red beds	1.56	199.62
22	Sandstone: green arkosic, coarse grained, three sequences 160, 243 and 22 cm thick begun by deep basal channel scour outlined by red mud-clasts, overlain by crossbeds and lamination, some red shale partings between cross sets	4.85	197.96
21	Sandstone: green, 80-160 cm beds, planar bedding planes, internally by planar lamination and cross beds, red mud-clasts, highly con-voluted structures in some beds, 20 cm red argillaceous sandstone bed 1 m above base	10.00	193.11
20	Sandstone and shale: gray, very fine and fine grained sand-stones, 15 cm thick, planar and wavy laminated; alternating with gray shale partings and 30 cm beds	0.72	183.11
19	Sandstones: green with some reddening, arkosic, coarse and medium grained, fining up in one sequence to very fine grained, in sequences 115 to 225 cm thick		

	separated by 10 to 27 cm of either green shale or green and/or red thin bedded and laminatedd siltstone with red shale partings. Sandstones have scour bases, planar thin stratification and lamination carrying parting lineation, some small scours in some units	5.52	182.39
18	Sandstone: green and some red, arkosic, coarse fining up into fine grained, locally pebbly, sequences 1 to 3 m thick of scour bases, locally showing current markings (current direction 046-226); internally dominated by planar lamination and cross beds towards top, locally convoluted structures, some 1 cm, angular pebbles of red rhyolite, granite and red mudclasts; beds and lenses, 10-20 cm thick, near top of each sequence consisting of red, mudcracked, mudstone, shale and siltstone, fine beds overlie or interbed with fine grained red, laminated and cross laminated sandstones, locally bioturbated	21.41	176.87
17	Sandstone and siltstone: red, very fine sandstone with shale laminae near base passing up into massive and laminated siltstone, mudcracks, bioturbationn and convolution of lamination	3.14	155.45
16	Sandstone: red, medium to coarse grained, broad, curved scour base, large scale cross beds and planar		

	lamination	2.62	152.32
15	Grit, conglomerate and shales: red, 1-2 m beds of grit, small pebble conglomerate, some very fine sandstone, separated by red shales up to 10 cm thick. Scour bases, large planar and smaller trough cross-beds. Pebbles of red granite, K-feldspar and dark red rhyolite	6.92	149.70
14	Sandstone: red and green, 80-160 cm beds, coarse grained with grit laminae, some very fine grained, mostly laminated, some ripple cross lamination, direction 230, local planar scours, mudcracked at tops	2.40	142.78
13	Sandstone and conglomerate: green and red, 60 to 120 cm beds, coarse to fine grained, channel scours, gritty and pebbly sandstone at base of unit. Small pebbles 4-6 mm in size of rhyolite, K-feldspar, granite, white quartzite and green argillite. Planar crossbeds overlain by lamination. Mostly sandstone separated by shale partings or beds 5-30 cm of red shales, scour bases some with flutes, some large scale planar crossbeds near base of beds overlain by planar lamination	11.42	140.38
12	Sandstone: red, very fine		

	grained, 20 cm beds separated by mudcracked shale partings, wavy lamination and ripple cross lamination	0.72	128.96
11	Sandstone: green, medium grained, 80-100 cm beds, scour bases, overlain by red mudclasts, cross beds and planar lamination	8.29	128.24
10	Sandstone: green to red, medium to very fine grained, fining upwards scour base, large cross-beds except in upper 100 cm. Here red sandstone consists of lamination and ripple cross lamination with silt-stone laminae and thin red shale interbeds	5.40	119.95
9	Sandstone: green and red, coarse to medium grained, 40-60 cm beds, some 5-10 cm gritty beds, erosive bases, red shale partings, some pebbles, crossbeds and planar lamination, some convolution of structures	17.84	114.55
8	Sandstone: gray, very fine to fine grained, micaceous, plant fossil debris, 10-36 cm beds separated by 1-5 cm red shales, planar bases and tops, lamination and ripple cross lamination, convolution, ripple marks, directions 115, 118 and 195	5.10	96.71
7	Sandstone-siltstone: green, medium grained sandstone grading up into red siltstones in 40 to 350 cm beds separated by red		

	shale partings, scour bases and channel scours, planar laminated with some crossbeds	50.36	91.61
6	Sandstone and shale: green to gray, fine to very fine grained, generally 40 cm planar beds, separated by 0-10 cm gray shale beds, micaceous plus fine plant fossil debris, gray shale clasts common, broad scour bases, lateral lensing out of beds,, planar lamination, and small scale cross beds or ripple cross lamination, convolution of structure, some load casts on bases of sandstones	10.23	41.25
5	Sandstone: green, arkosic, coarse to medium grained, rich in gray shale intra-clasts, cross beds and planar lamination	3.50	31.02
4	Sandstone: red, coarse grained, granules in thin layers, planar lamination and large trough cross beds	2.55	27.52
3	Sandstone: green, fine grained, micaceous, fine plant fossil debris, broad scours and some trough scours, mostly planar lamination with parting lineation, some cross lamination	9.80	24.97
2	Sandstone: green and red, medium to fine grained, arkosic and micaceous, beds up to 100 cm thick, separated by mudcracked red shale partings, internally		

	beds of planar lamination with parting lineations and cross beds, ripple marks near top of beds	8.70	15.17
1	Sandstone: green to red, arkosic, medium fining up into fine grained, large cross beds, shale partings	6.47	6.47

Basal contact is gradational; placed at base of first sandstone unit that includes red beds 1 m thick. Base overlies unit 56 of the section of Friars Cove Formation.

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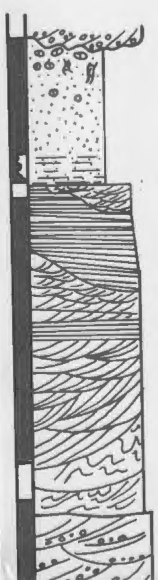

few centimetres in other sections of the formation (von Bitter and Plint-Geberl, 1982).

On Codroy Island in the south, well sorted gray sandstones and intraformational limestone breccias, not found elsewhere in the subbasin, occur interbedded with the limestones (Figure 19). Synsedimentary deformation of the limestones is also seen on the island.

Different sections contain minor deposits of oolitic limestone, massive limestone, thin gray-green shales, red mudstone and fine gray sandstone beds or laminae. Seven lithofacies are defined from field and petrographic data. In field sections, the lithofacies are generally arranged in a vertical sequence in which facies A is overlain by B which is in turn overlain by C. This sequential order was observed by the author in the Macumber Formation at Whycocomagh, Cape Breton and it was also stressed by Geldsetzer (1978) in his interpretation of the basal Windsor limestone. The lithofacies (Table 5), are as follows: (A) stratified packstone lithofacies; (B) laminite lithofacies; (C) moldic, argillaceous and shaly laminite lithofacies; (D) intraformational limestone-breccia lithofacies; (E) oolitic-limestone lithofacies; (F) sandstone lithofacies and (G) other rock types.

(A) Stratified packstone lithofacies

Description of lithohfacies A: In most localities, lithofacies A forms the basal 20-175 cm of the formation; 5 to 40 cm thick units